BGP for Internet Service Providers

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Cisco Systems

Presentation Slides

- **Available on RIPE meeting Web site**

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- **Feel free to ask questions**

BGP for Internet Service Providers

- BGP Basics (quick recap)
- Scaling BGP
- Deploying BGP in an ISP network
- Trouble & Troubleshooting
- Multihoming Examples
- Using Communities

BGP Basics

What is this BGP thing?

Border Gateway Protocol

- Routing Protocol used to exchange routing information between networks

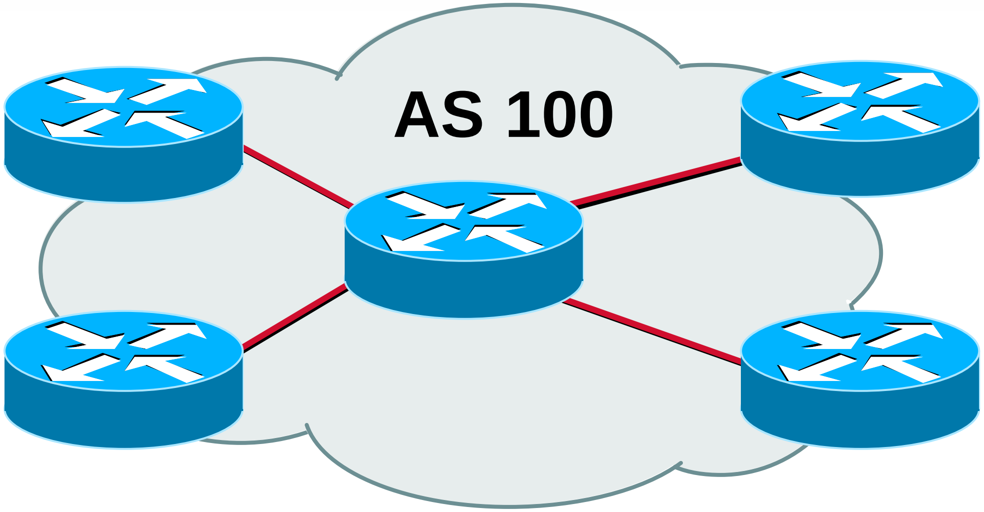
  exterior gateway protocol

- RFC1771

  work in progress to update

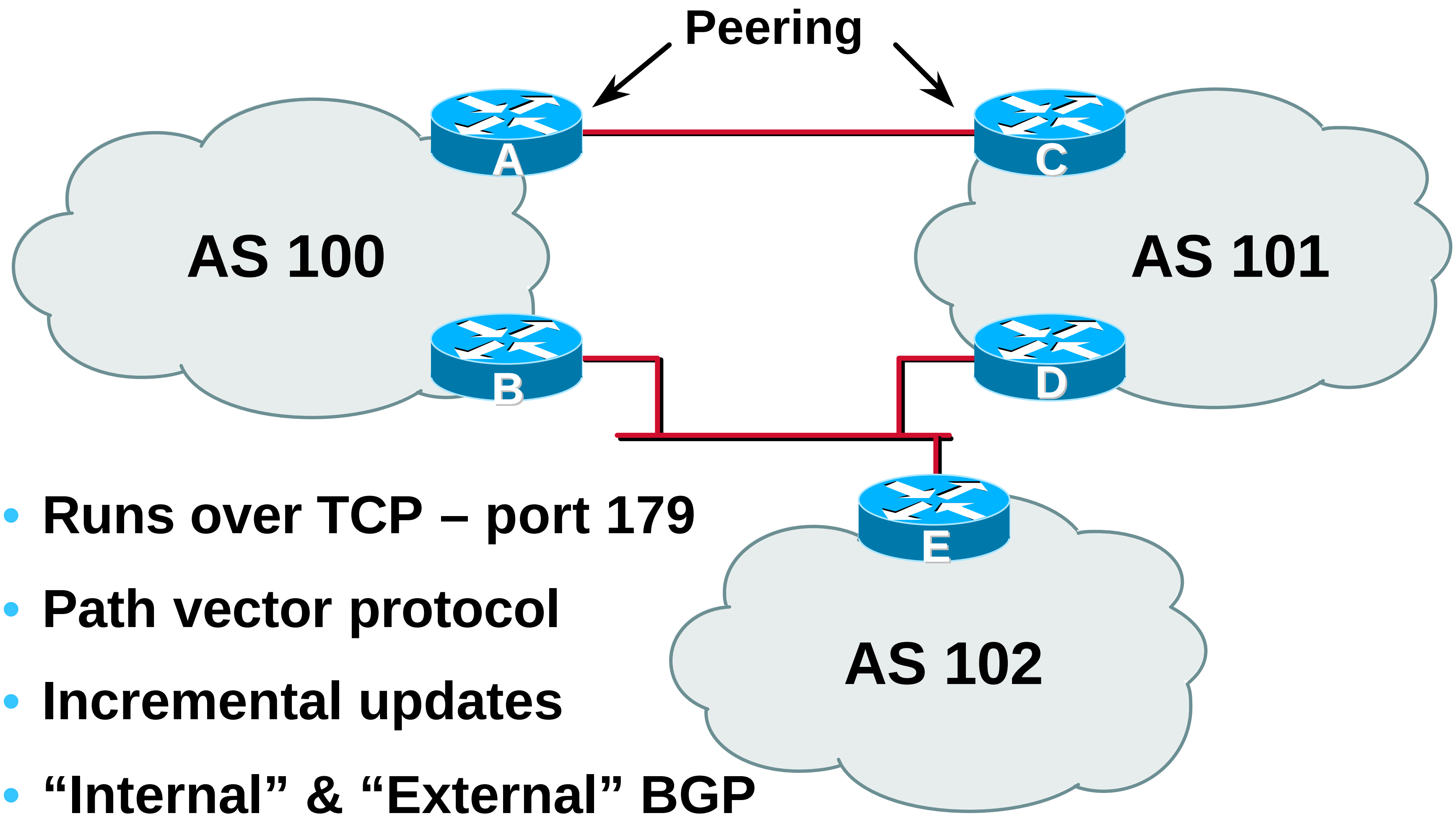
  `draft-ietf-idr-bgp4-13.txt`

Autonomous System (AS)



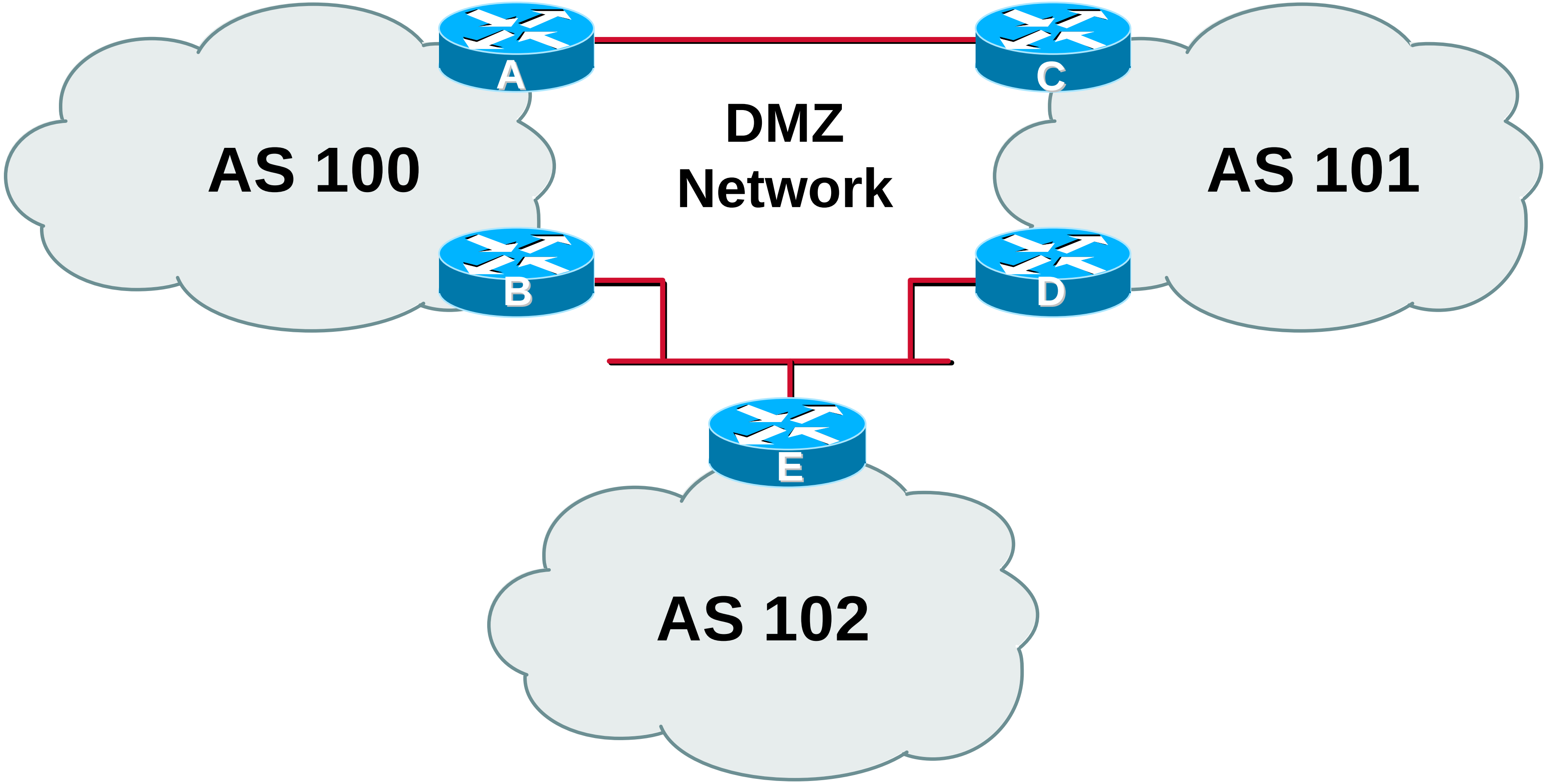
- **Collection of networks with same routing policy**
- **Single routing protocol**
- **Usually under single ownership, trust and administrative control**

BGP Basics



- Runs over TCP – port 179
- Path vector protocol
- Incremental updates
- “Internal” & “External” BGP

Demarcation Zone (DMZ)

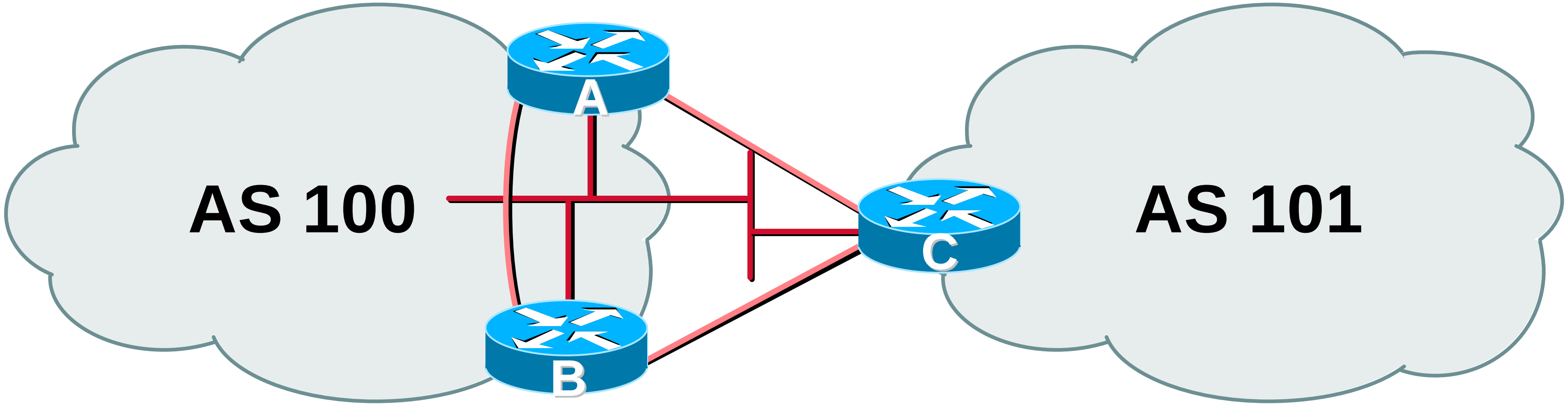


- **Shared network between ASes**

BGP General Operation

- Learns multiple paths via internal and external BGP speakers
- Picks the best path and installs in the forwarding table
- Best path is sent to external BGP neighbours
- Policies applied by influencing the best path selection

External BGP Peering (eBGP)



- Between BGP speakers in different AS
- Should be directly connected
- Never run an IGP between eBGP peers

Configuring External BGP

Router A in AS100

```
interface ethernet 5/0
ip address 222.222.10.2 255.255.255.240
router bgp 100
 network 220.220.8.0 mask 255.255.252.0
 neighbor 222.222.10.1 remote-as 101
 neighbor 222.222.10.1 prefix-list RouterC in
 neighbor 222.222.10.1 prefix-list RouterC out
```

Router C in AS101

```
interface ethernet 1/0/0
ip address 222.222.10.1 255.255.255.240
router bgp 101
 network 220.220.16.0 mask 255.255.240.0
 neighbor 222.222.10.2 remote-as 100
 neighbor 222.222.10.2 prefix-list RouterA in
 neighbor 222.222.10.2 prefix-list RouterA out
```

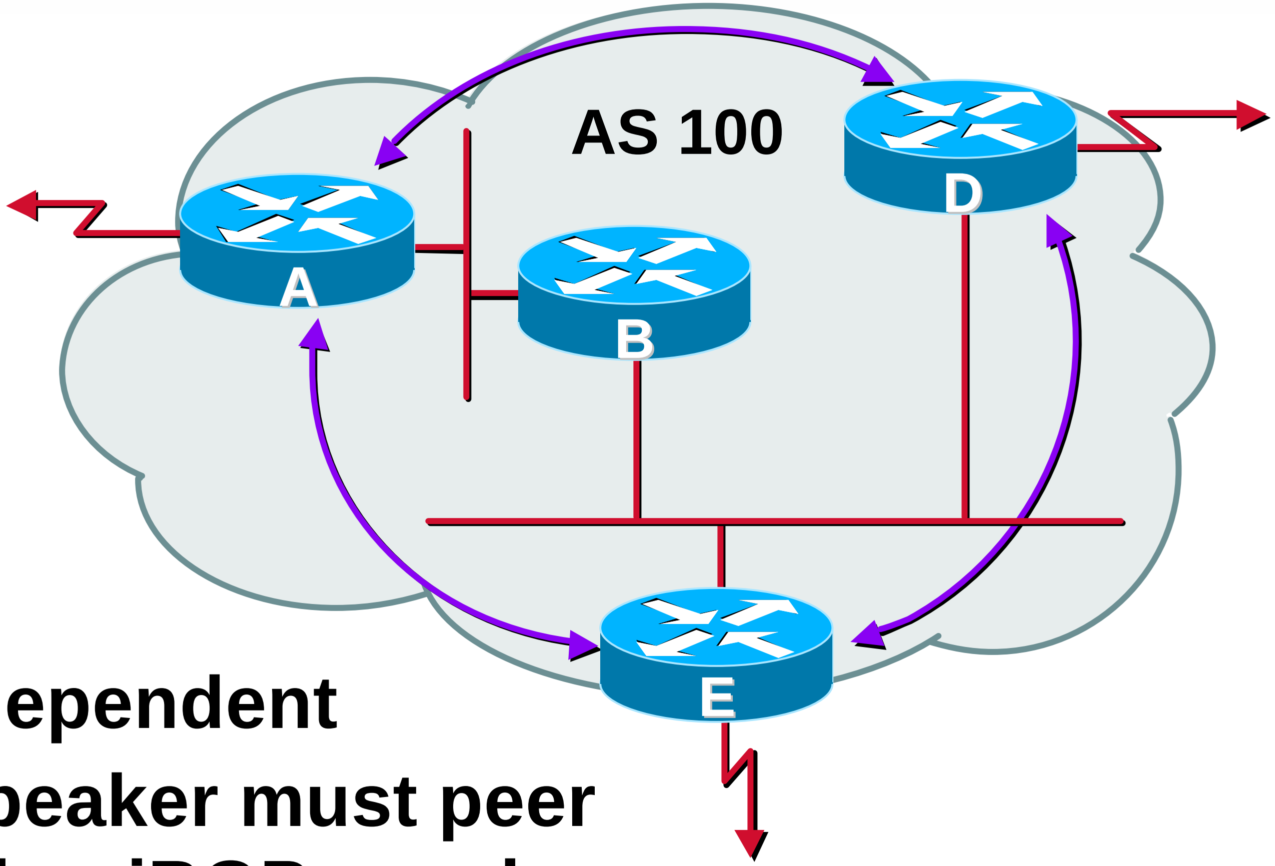
Internal BGP (iBGP)

- BGP peer within the same AS
- Not required to be directly connected
- iBGP speakers need to be fully meshed

  they originate connected networks

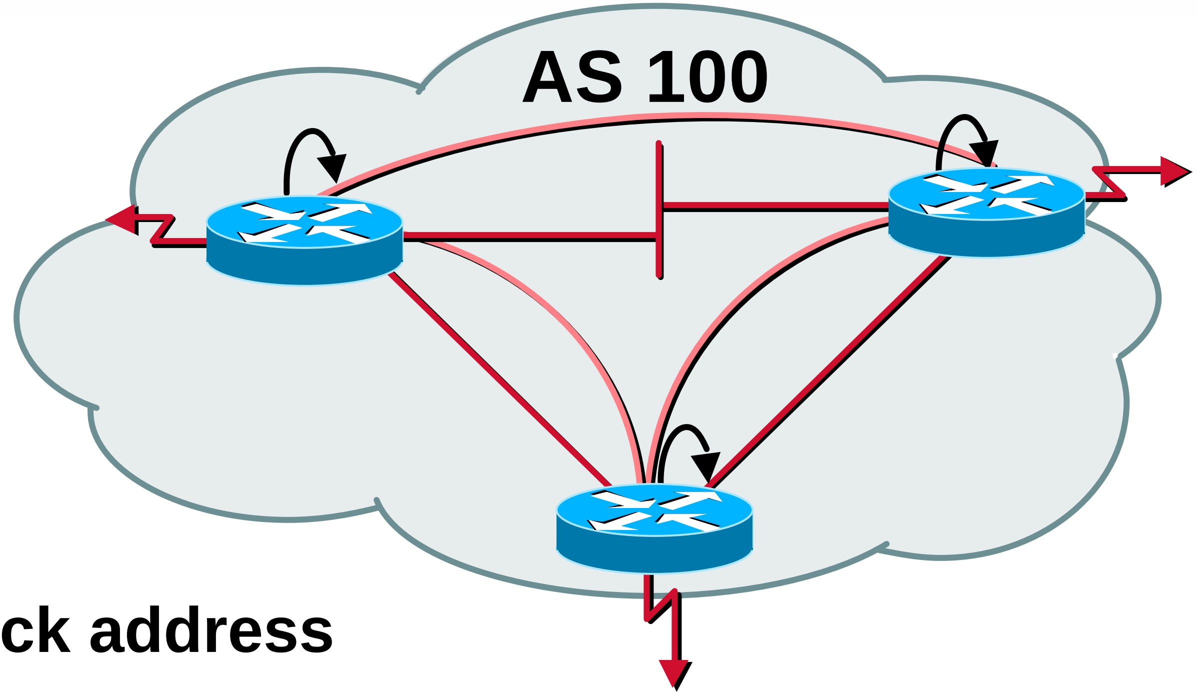
  they do not pass on prefixes learned from other iBGP speakers

Internal BGP Peering (iBGP)



- Topology independent
- Each iBGP speaker must peer with every other iBGP speaker in the AS

Peering to Loop-Back Address



- **Peer with loop-back address**

  Loop-back interface does not go down – ever!

- **iBGP session is not dependent on state of a single interface**

- **iBGP session is not dependent on physical topology**

Configuring Internal BGP

Router A

```
interface loopback 0
ip address 215.10.7.1 255.255.255.255
router bgp 100
  network 220.220.1.0
  neighbor 215.10.7.2 remote-as 100
  neighbor 215.10.7.2 update-source loopback0
  neighbor 215.10.7.3 remote-as 100
  neighbor 215.10.7.3 update-source loopback0
```

Router B

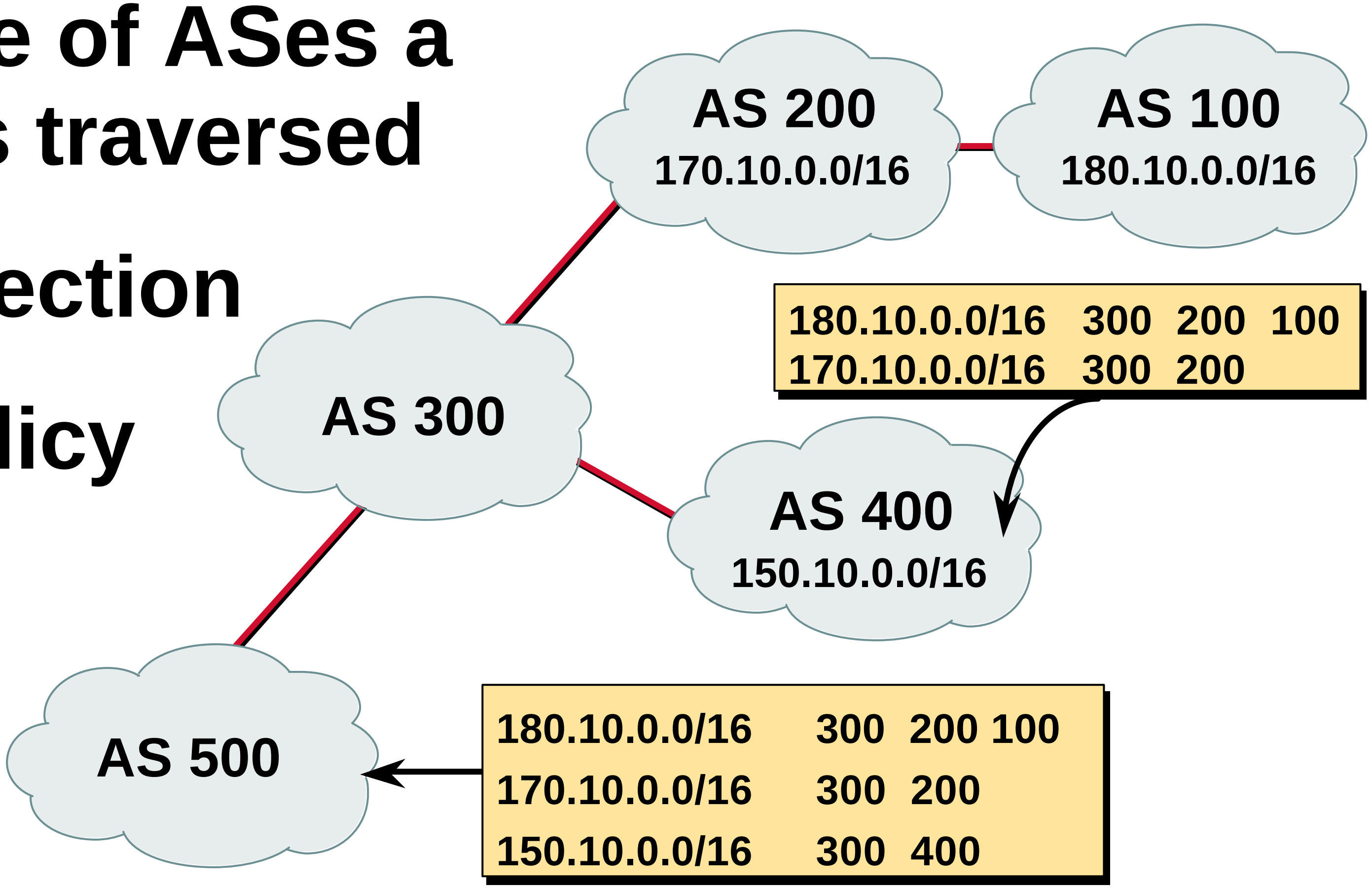
```
interface loopback 0
ip address 215.10.7.2 255.255.255.255
router bgp 100
  network 220.220.5.0
  neighbor 215.10.7.1 remote-as 100
  neighbor 215.10.7.1 update-source loopback0
  neighbor 215.10.7.3 remote-as 100
  neighbor 215.10.7.3 update-source loopback0
```

BGP Attributes

Recap

AS-Path

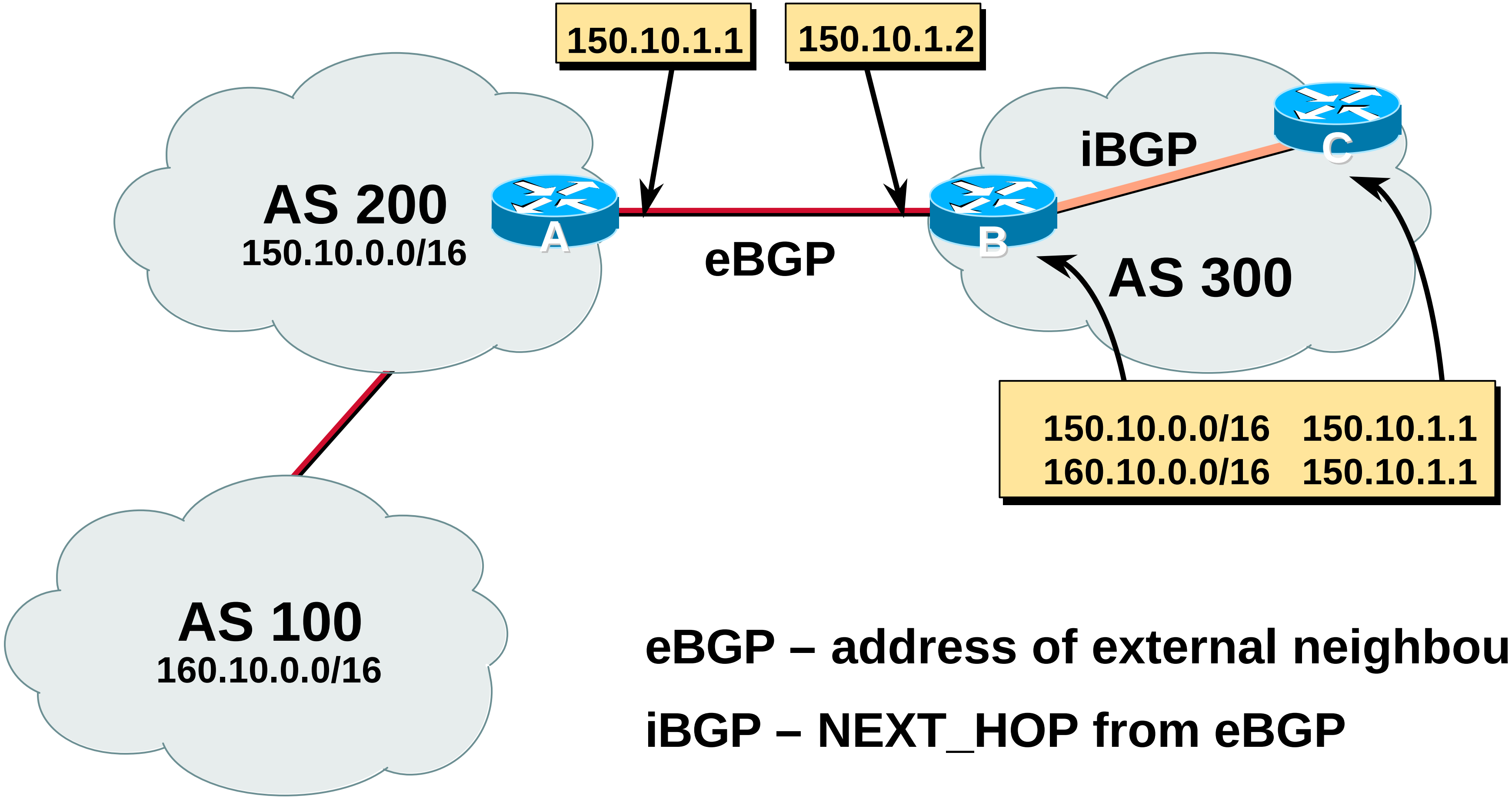
- Sequence of ASes a route has traversed
- Loop detection
- Apply policy



180.10.0.0/16	300 200 100
170.10.0.0/16	300 200

180.10.0.0/16	300 200 100
170.10.0.0/16	300 200
150.10.0.0/16	300 400

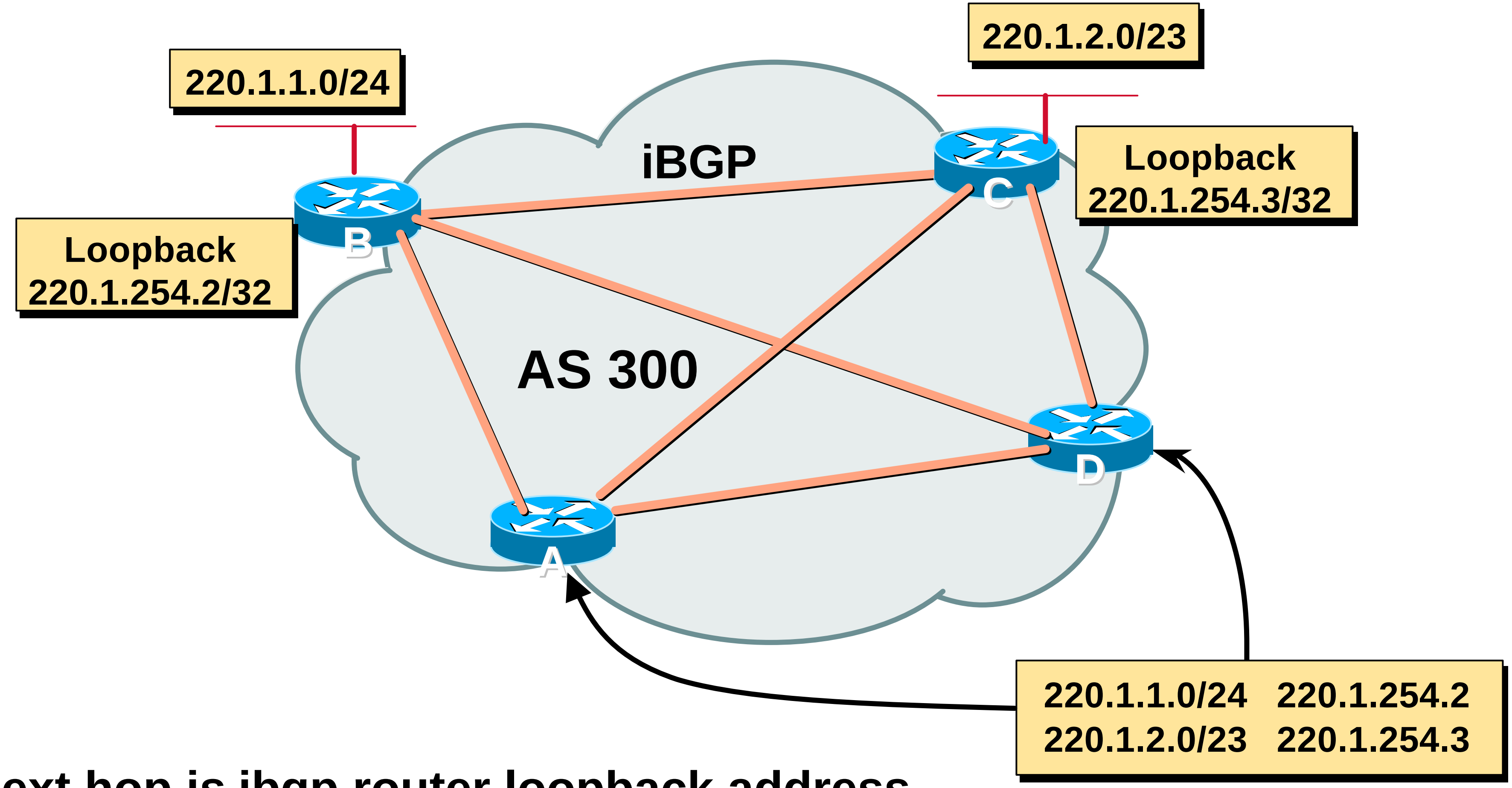
Next Hop



eBGP – address of external neighbour

iBGP – NEXT_HOP from eBGP

iBGP Next Hop



220.1.1.0/24

Loopback
220.1.254.2/32

220.1.2.0/23

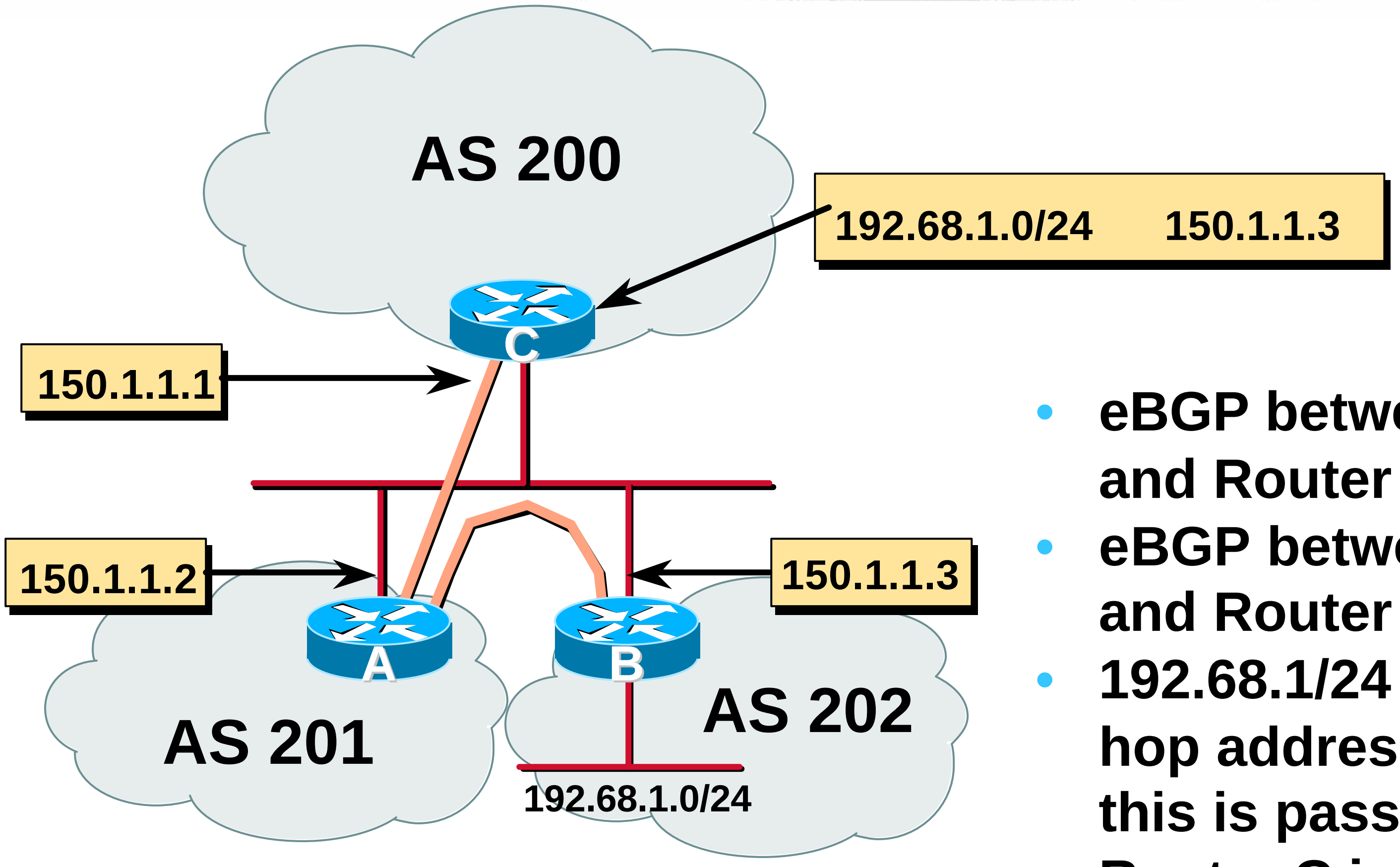
Loopback
220.1.254.3/32

220.1.1.0/24	220.1.254.2
220.1.2.0/23	220.1.254.3

Next hop is ibgp router loopback address

Recursive route look-up

Third Party Next Hop



- eBGP between Router A and Router C
- eBGP between Router A and Router B
- 192.68.1/24 prefix has next hop address of 150.1.1.3 – this is passed on to Router C instead of 150.1.1.2

Next Hop (summary)

- IGP should carry route to next hops
- Recursive route look-up
- Unlinks BGP from actual physical topology
- Allows IGP to make intelligent forwarding decision

Origin

- Conveys the origin of the prefix
- “Historical” attribute
- Influences best path selection
- Three values: IGP, EGP, incomplete

    IGP – generated by BGP network statement

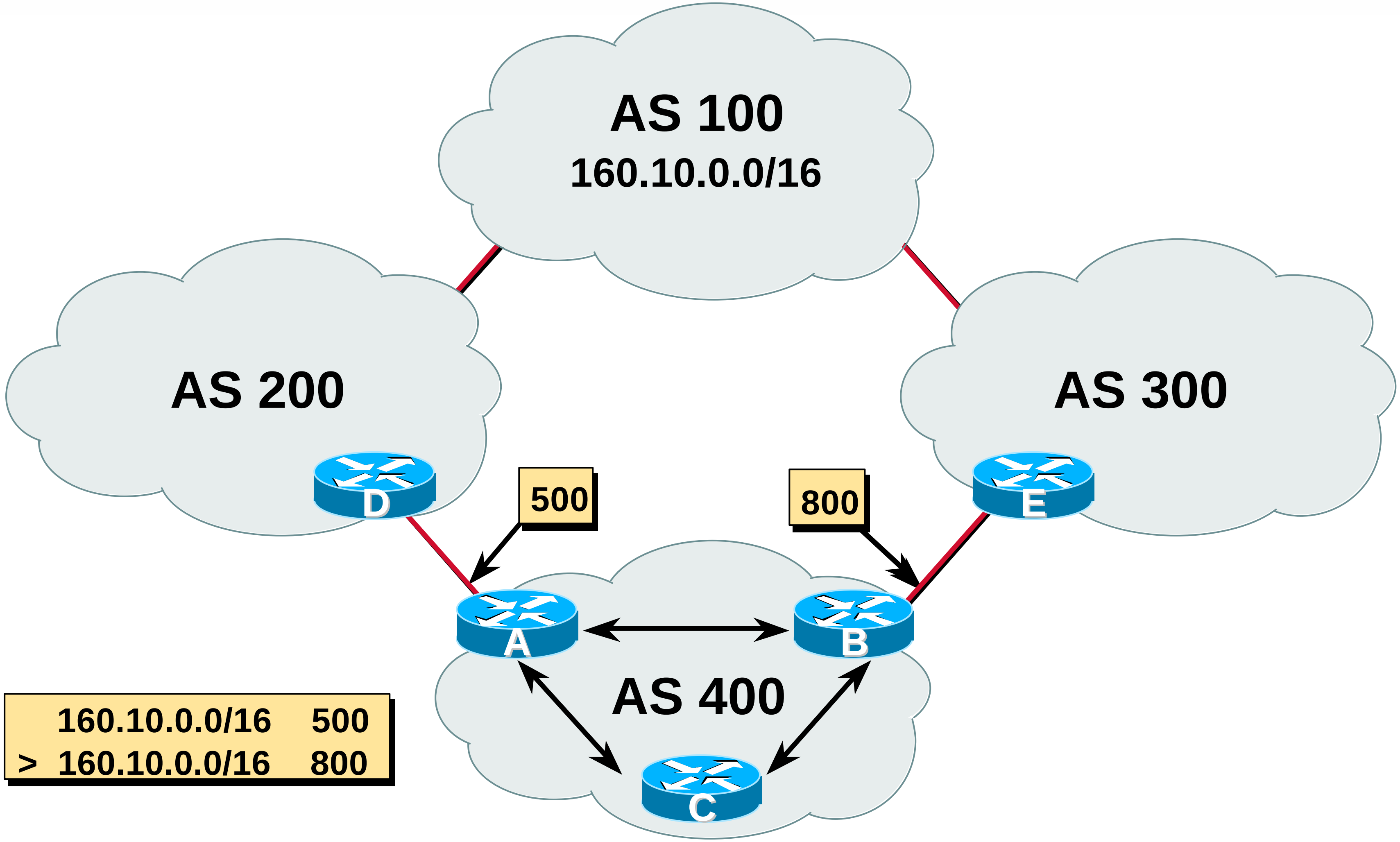
    EGP – generated by EGP

    incomplete – redistributed from another routing protocol

Aggregator

- Conveys the IP address of the router/BGP speaker generating the aggregate route
- Useful for debugging purposes
- Does not influence best path selection

Local Preference



	160.10.0.0/16	500
>	160.10.0.0/16	800

Local Preference

- **Local to an AS – non-transitive**

  Default local preference is 100

- **Used to influence BGP path selection**

  determines best path for *outbound* traffic

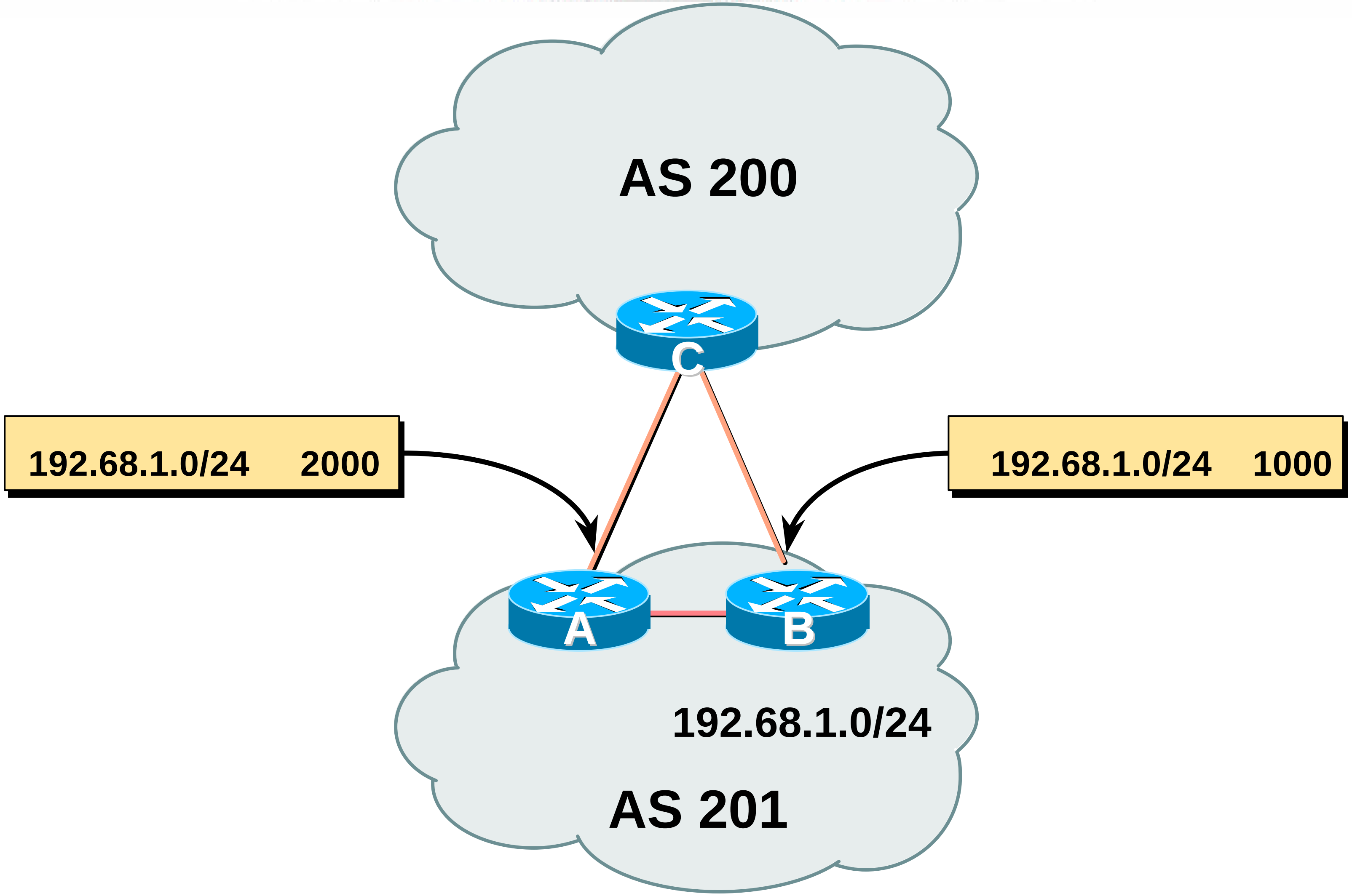
- **Path with highest local preference wins**

Local Preference

- Configuration of Router B:

```
router bgp 400
 neighbor 220.5.1.1 remote-as 300
 neighbor 220.5.1.1 route-map local-pref in
!
route-map local-pref permit 10
 match ip address prefix-list MATCH
 set local-preference 800
!
ip prefix-list MATCH permit 160.10.0.0/16
```

Multi-Exit Discriminator (MED)



Multi-Exit Discriminator

- **Inter-AS – non-transitive**
- **Used to convey the relative preference of entry points**

  determines best path for *inbound* traffic
- **Comparable if paths are from same AS**
- **IGP metric can be conveyed as MED**

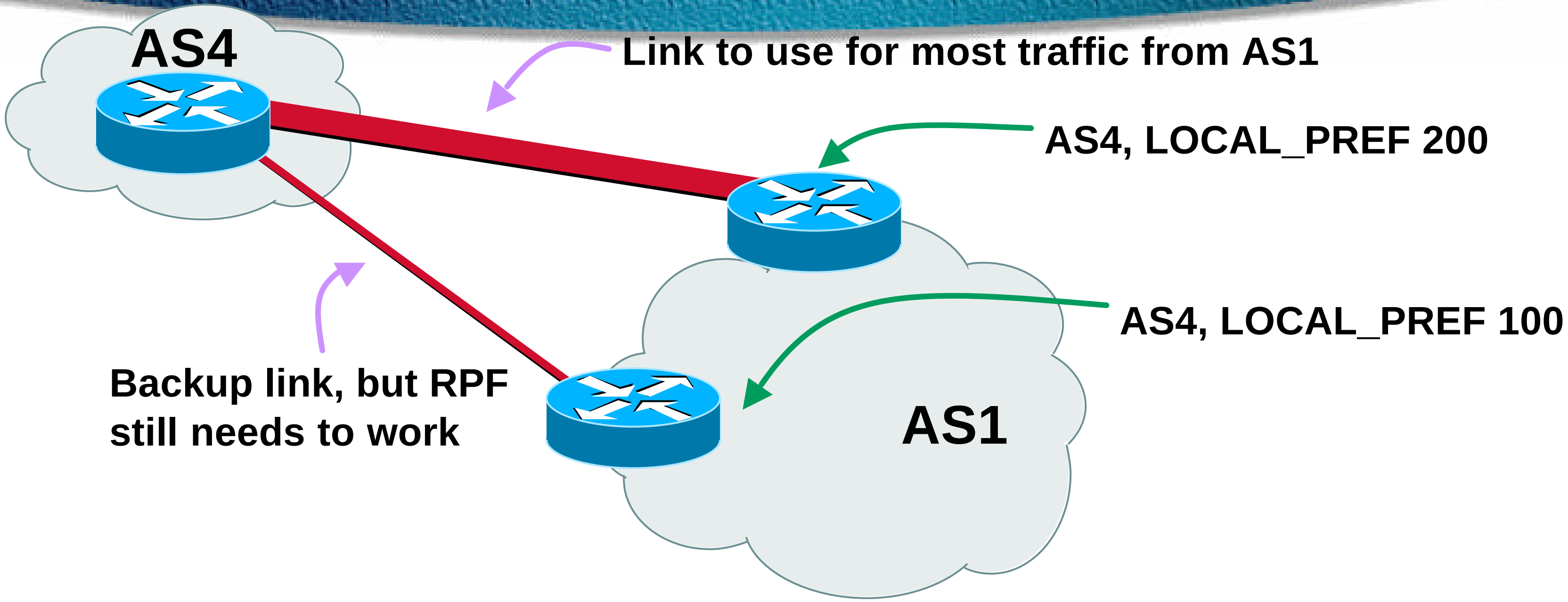
  set metric-type internal in route-map

Multi-Exit Discriminator

- Configuration of Router B:

```
router bgp 400
 neighbor 220.5.1.1 remote-as 200
 neighbor 220.5.1.1 route-map set-med out
!
route-map set-med permit 10
 match ip address prefix-list MATCH
 set metric 1000
!
ip prefix-list MATCH permit 192.68.1.0/24
```

Weight – used to deploy RPF



- **Local to router on which it's configured**

  Not really an attribute

- **route-map: *set weight***
- **Highest weight wins over all valid paths**
- **Weight customer eBGP on edge routers to allow RPF to work correctly**

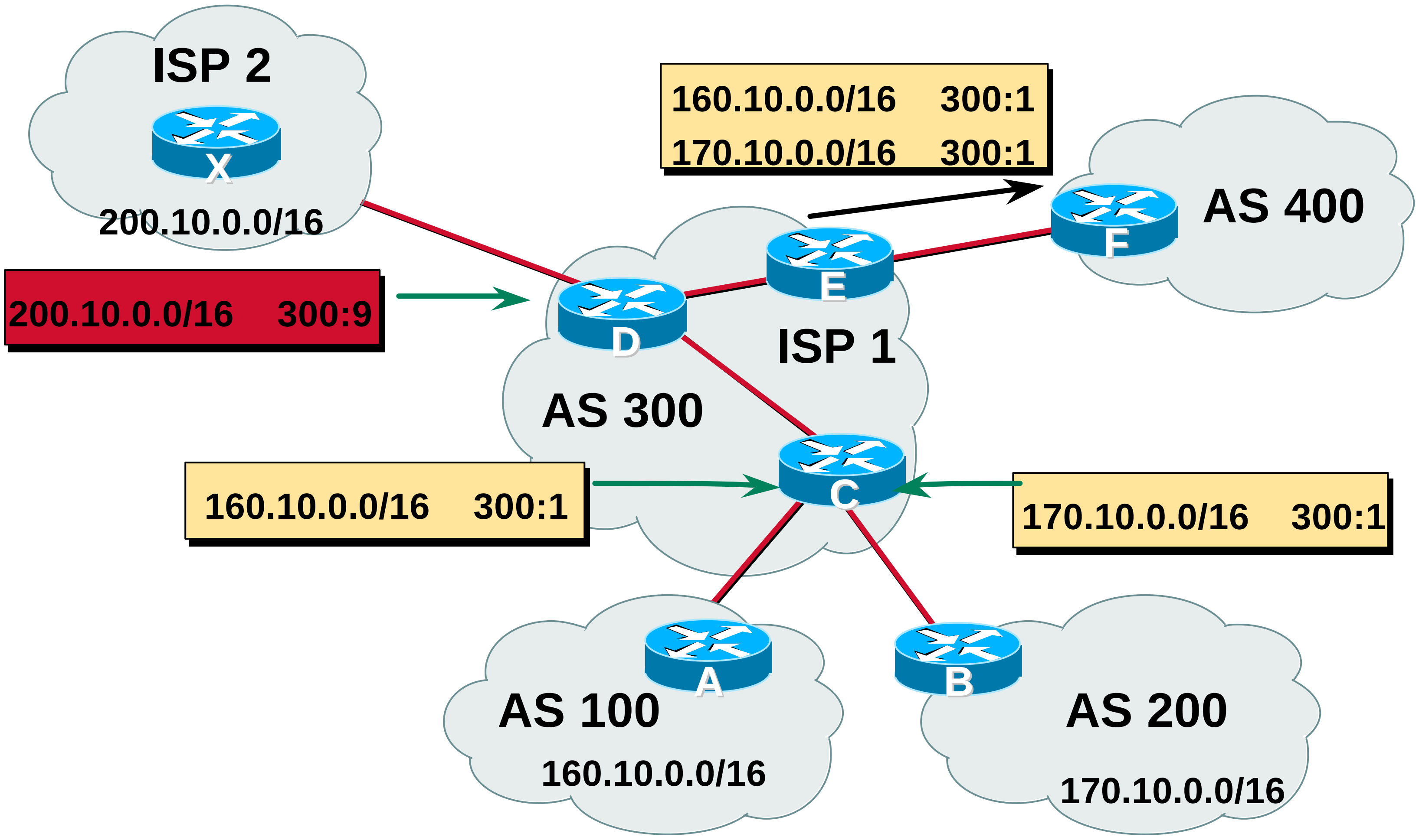
Community

- BGP attribute
- Described in RFC1997
- 32 bit integer

  Represented as two 16 bit integers
- Used to group destinations

  Each destination could be member of multiple communities
- Community attribute carried across AS's
- Very useful in applying policies

Community



ISP 2
X
200.10.0.0/16
160.10.0.0/16 300:1
170.10.0.0/16 300:1
AS 400
F
E
200.10.0.0/16 300:9
D
ISP 1
AS 300
160.10.0.0/16 300:1
C
170.10.0.0/16 300:1
A
B
AS 100
160.10.0.0/16
AS 200
170.10.0.0/16

Well-Known Communities

- **no-export**

  do not advertise to eBGP peers

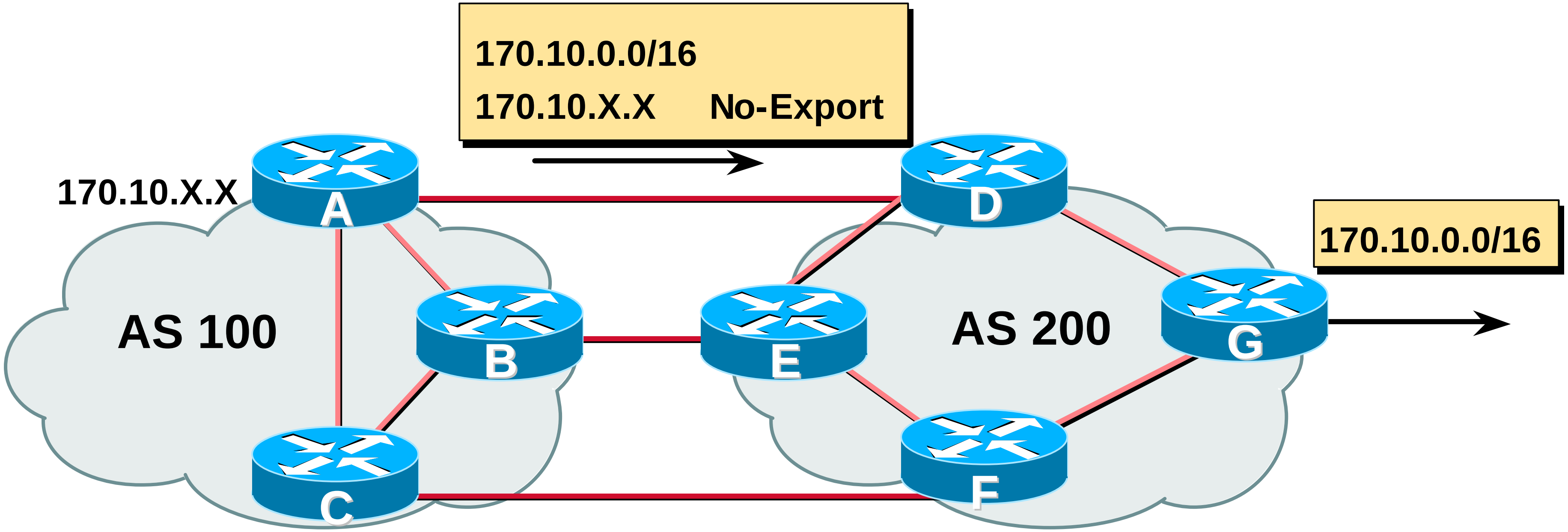
- **no-advertise**

  do not advertise to any peer

- **local-AS**

  do not advertise outside local AS (only used with confederations)

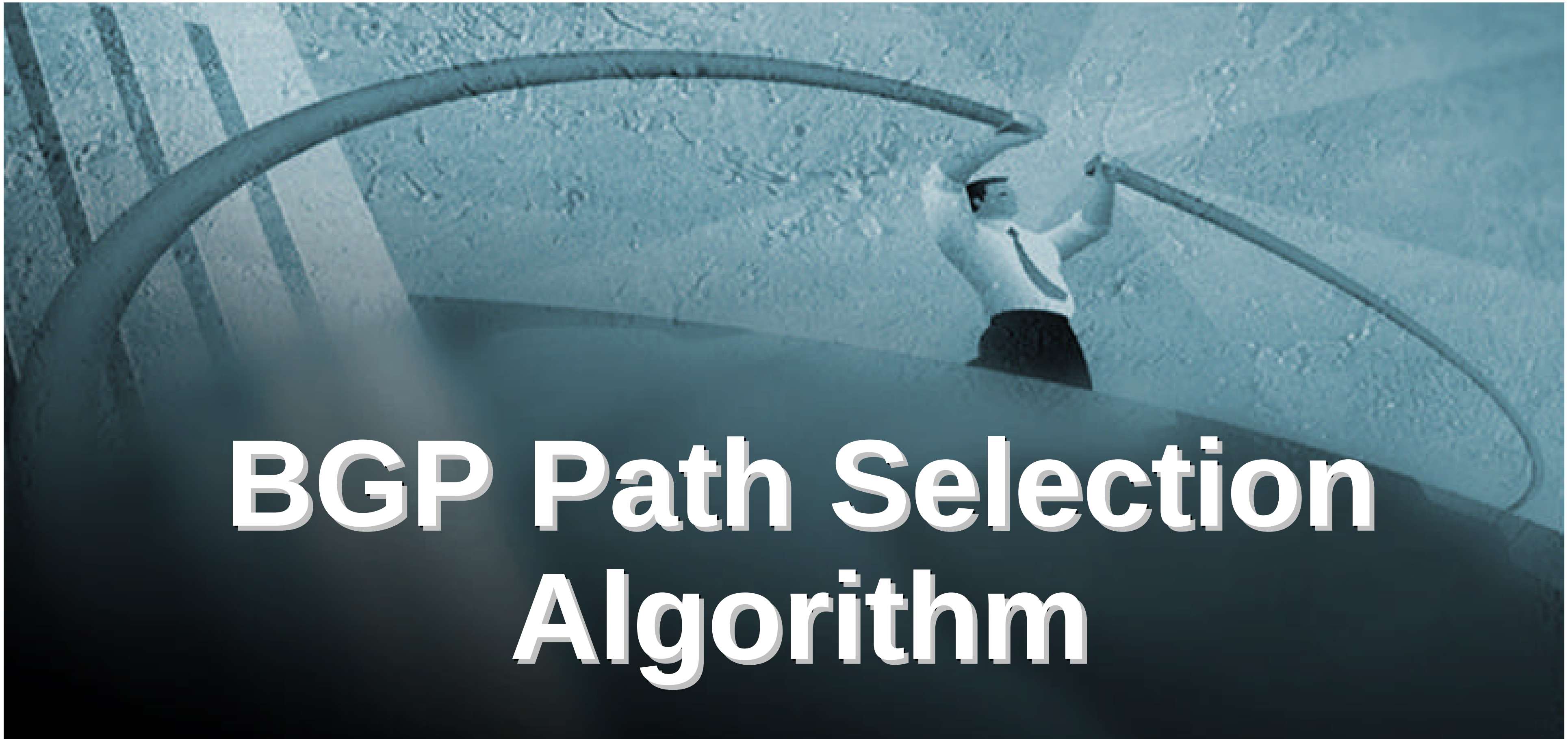
No-Export Community



- AS100 announces aggregate and subprefixes

  aim is to improve loadsharing by leaking subprefixes

- Subprefixes marked with no-export community
- Router G in AS200 does not announce prefixes with no-export community set



BGP Path Selection Algorithm

Why is this the best path?

BGP Path Selection Algorithm

- Do not consider path if no route to next hop
- Do not consider iBGP path if not synchronised (Cisco IOS)
- Highest weight (local to router)
- Highest local preference (global within AS)
- Prefer locally originated route
- Shortest AS path

BGP Path Selection Algorithm (continued)

- Lowest origin code

  IGP < EGP < incomplete

- Lowest Multi-Exit Discriminator (MED)

  If bgp deterministic-med, order the paths before comparing

  If bgp always-compare-med, then compare for all paths

  otherwise MED only considered if paths are from the same AS (default)

BGP Path Selection Algorithm (continued)

- Prefer eBGP path over iBGP path
- Path with lowest IGP metric to next-hop
- Lowest router-id (originator-id for reflected routes)
- Shortest Cluster-List

  Client must be aware of Route Reflector attributes!

- Lowest neighbour IP address

Applying Policy with BGP

Control!

Applying Policy with BGP

- Applying Policy
  - Decisions based on AS path, community or the prefix
  - Rejecting/accepting selected routes
  - Set attributes to influence path selection
- Tools:
  - Prefix-list (filter prefixes)
  - Filter-list (filter ASes)
  - Route-maps and communities

Policy Control
Prefix List

- Filter routes based on prefix
- Inbound and Outbound

```
router bgp 200
 neighbor 220.200.1.1 remote-as 210
 neighbor 220.200.1.1 prefix-list PEER-IN in
 neighbor 220.200.1.1 prefix-list PEER-OUT out
!
ip prefix-list PEER-IN deny 218.10.0.0/16
ip prefix-list PEER-IN permit 0.0.0.0/0 le 32
ip prefix-list PEER-OUT permit 215.7.0.0/16
```

Policy Control
Filter List

- **Filter routes based on AS path**
- **Inbound and Outbound**

```
router bgp 100
 neighbor 220.200.1.1 remote-as 210
 neighbor 220.200.1.1 filter-list 5 out
 neighbor 220.200.1.1 filter-list 6 in
!
ip as-path access-list 5 permit ^200$
ip as-path access-list 6 permit ^150$
```

Policy Control
Regular Expressions

- Like Unix regular expressions

.	Match one character
*	Match any number of preceding expression
+	Match at least one of preceding expression
^	Beginning of line
$	End of line
_	Beginning, end, white-space, brace
|	Or
()	brackets to contain expression

Policy Control
Regular Expressions

- **Simple Examples**

.*	Match anything
.+	Match at least one character
^$	Match routes local to this AS
_1800$	Originated by 1800
^1800_	Received from 1800
_1800_	Via 1800
_790_1800_	Passing through 1800 then 790
_(1800_)+	Match at least one of 1800 in sequence
_\(65350\)_	Via 65350 (confederation AS)

Policy Control
Route Maps

- A route-map is like a “programme” for IOS
- Has “line” numbers, like programmes
- Each line is a separate condition/action
- Concept is basically:

```
if match then do expression and exit
else
if match then do expression and exit
else etc
```

Policy Control
Route Maps

- **Example using prefix-lists**

```
router bgp 100
 neighbor 1.1.1.1 route-map infilter in
!
route-map infilter permit 10
 match ip address prefix-list HIGH-PREF
 set local-preference 120
!
route-map infilter permit 20
 match ip address prefix-list LOW-PREF
 set local-preference 80
!
route-map infilter permit 30
!
ip prefix-list HIGH-PREF permit 10.0.0.0/8
ip prefix-list LOW-PREF permit 20.0.0.0/8
```

Policy Control
Route Maps

- **Example using filter lists**

```
router bgp 100
 neighbor 220.200.1.2 route-map filter-on-as-path in
!
route-map filter-on-as-path permit 10
 match as-path 1
 set local-preference 80
!
route-map filter-on-as-path permit 20
 match as-path 2
 set local-preference 200
!
route-map filter-on-as-path permit 30
!
ip as-path access-list 1 permit _150$
ip as-path access-list 2 permit _210_
```

Policy Control
Route Maps

- Example configuration of AS-PATH prepend

```
router bgp 300
 network 215.7.0.0
 neighbor 2.2.2.2 remote-as 100
 neighbor 2.2.2.2 route-map SETPATH out
!
route-map SETPATH permit 10
 set as-path prepend 300 300
```

- Use your own AS number when prepending

  Otherwise BGP loop detection may cause disconnects

Policy Control
Setting Communities

- Example Configuration

```
router bgp 100
 neighbor 220.200.1.1 remote-as 200
 neighbor 220.200.1.1 send-community
 neighbor 220.200.1.1 route-map set-community out
!
route-map set-community permit 10
 match ip address prefix-list NO-ANNOUNCE
 set community no-export
!
route-map set-community permit 20
!
ip prefix-list NO-ANNOUNCE permit 172.168.0.0/16 ge 17
```

Policy Control
Matching Communities

- Example Configuration

```
router bgp 100
 neighbor 220.200.1.2 remote-as 200
 neighbor 220.200.1.2 route-map filter-on-community in
!
route-map filter-on-community permit 10
 match community 1
 set local-preference 50
!
route-map filter-on-community permit 20
 match community 2 exact-match
 set local-preference 200
!
ip community-list 1 permit 150:3 200:5
ip community-list 2 permit 88:6
```

BGP Capabilities

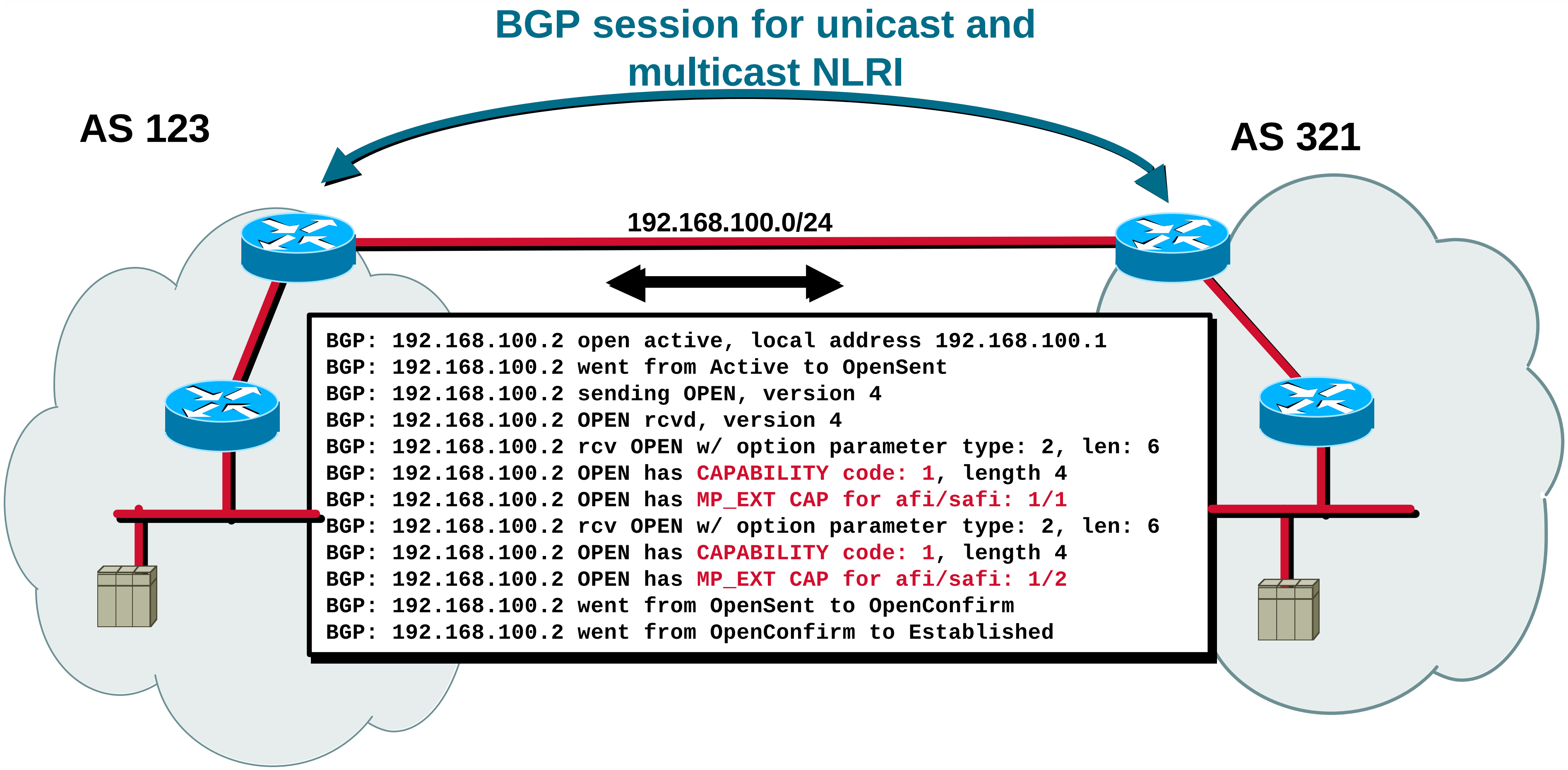
Extending BGP

BGP Capabilities

- Documented in RFC2842
- Capabilities parameters passed in BGP open message
- Unknown or unsupported capabilities will result in NOTIFICATION message
- Current capabilities are:

0	Reserved	[RFC2842]
1	Multiprotocol Extensions for BGP-4	[RFC2858]
2	Route Refresh Capability for BGP-4	[RFC2918]
3	Cooperative Route Filtering Capability	[]
4	Multiple routes to a destination capability	[RFC3107]
64	Graceful Restart Capability	[]

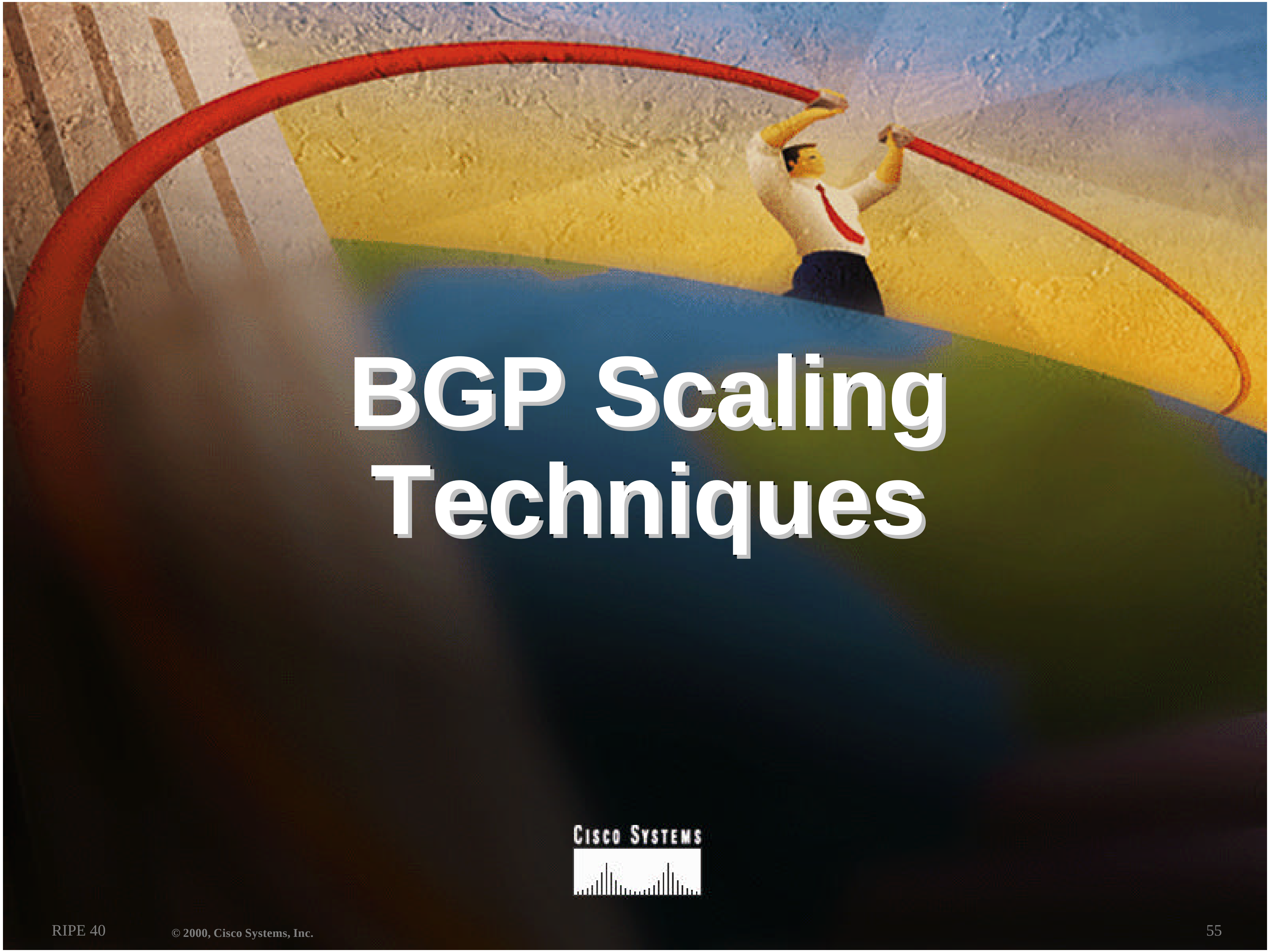
BGP Capabilities Negotiation



```
BGP: 192.168.100.2 open active, local address 192.168.100.1
BGP: 192.168.100.2 went from Active to OpenSent
BGP: 192.168.100.2 sending OPEN, version 4
BGP: 192.168.100.2 OPEN rcvd, version 4
BGP: 192.168.100.2 rcv OPEN w/ option parameter type: 2, len: 6
BGP: 192.168.100.2 OPEN has CAPABILITY code: 1, length 4
BGP: 192.168.100.2 OPEN has MP_EXT CAP for afi/safi: 1/1
BGP: 192.168.100.2 rcv OPEN w/ option parameter type: 2, len: 6
BGP: 192.168.100.2 OPEN has CAPABILITY code: 1, length 4
BGP: 192.168.100.2 OPEN has MP_EXT CAP for afi/safi: 1/2
BGP: 192.168.100.2 went from OpenSent to OpenConfirm
BGP: 192.168.100.2 went from OpenConfirm to Established
```

BGP for Internet Service Providers

- BGP Basics (quick recap)
- Scaling BGP
- Deploying BGP in an ISP network
- Trouble & Troubleshooting
- Multihoming Examples
- Using Communities



BGP Scaling Techniques

BGP Scaling Techniques

- How to scale iBGP mesh beyond a few peers?
- How to implement new policy without causing flaps and route churning?
- How to reduce the overhead on the routers?
- How to keep the network stable, scalable, as well as simple?

BGP Scaling Techniques

- Dynamic Reconfiguration
- Peer groups
- Route flap damping
- Route Reflectors & Confederations

Dynamic Reconfiguration

Soft Reconfiguration and Route Refresh

Soft Reconfiguration

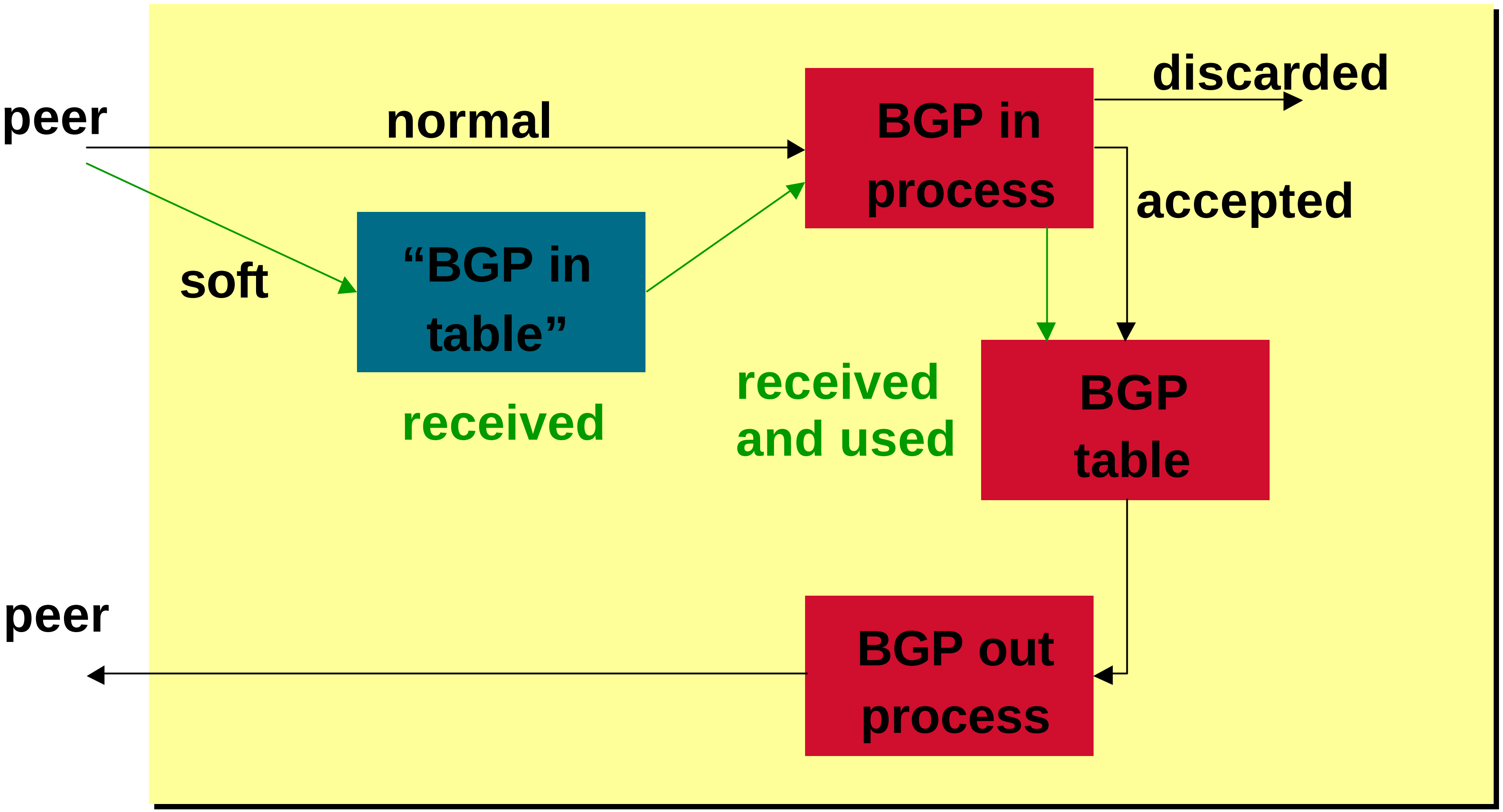
Problem:

- Hard BGP peer clear required after every policy change because the router does not store prefixes that are denied by a filter
- Hard BGP peer clearing consumes CPU and affects connectivity for all networks

Solution:

- Soft-reconfiguration

Soft Reconfiguration



Soft Reconfiguration

- New policy is activated without tearing down and restarting the peering session
- Per-neighbour basis
- Use more memory to keep prefixes whose attributes have been changed or have not been accepted

Configuring Soft reconfiguration

```
router bgp 100
 neighbor 1.1.1.1 remote-as 101
 neighbor 1.1.1.1 route-map infilter in
 neighbor 1.1.1.1 soft-reconfiguration inbound
```

! *Outbound does not need to be configured* !

Then when we change the policy, we issue an exec command

```
clear ip bgp 1.1.1.1 soft [in | out]
```

Route Refresh Capability

- Facilitates non-disruptive policy changes
- No configuration is needed
- No additional memory is used
- Requires peering routers to support “route refresh capability” – RFC2918
- clear ip bgp x.x.x.x in tells peer to resend full BGP announcement

Soft Reconfiguration vs Route Refresh

- Use Route Refresh capability if supported

  find out from "show ip bgp neighbor"

  uses much less memory

- Otherwise use Soft Reconfiguration

- Only hard-reset a BGP peering as a last resort

Peer Groups

Peer Groups

Without peer groups

- iBGP neighbours receive same update
- Large iBGP mesh slow to build
- Router CPU wasted on repeat calculations

Solution – peer groups!

- Group peers with same outbound policy
- Updates are generated once per group

Peer Groups – Advantages

- Makes configuration easier
- Makes configuration less prone to error
- Makes configuration more readable
- Lower router CPU load
- iBGP mesh builds more quickly
- Members can have different inbound policy
- Can be used for eBGP neighbours too!

Configuring Peer Group

```
router bgp 100
 neighbor ibgp-peer peer-group
 neighbor ibgp-peer remote-as 100
 neighbor ibgp-peer update-source loopback 0
 neighbor ibgp-peer send-community
 neighbor ibgp-peer route-map outfilter out
 neighbor 1.1.1.1 peer-group ibgp-peer
 neighbor 2.2.2.2 peer-group ibgp-peer
 neighbor 2.2.2.2 route-map  infilter in
 neighbor 3.3.3.3 peer-group ibgp-peer
```

! *note how 2.2.2.2 has different inbound filter from peer-group* !

Configuring Peer Group

```
router bgp 109
 neighbor external-peer peer-group
 neighbor external-peer send-community
 neighbor external-peer route-map set-metric out
 neighbor 160.89.1.2 remote-as 200
 neighbor 160.89.1.2 peer-group external-peer
 neighbor 160.89.1.4 remote-as 300
 neighbor 160.89.1.4 peer-group external-peer
 neighbor 160.89.1.6 remote-as 400
 neighbor 160.89.1.6 peer-group external-peer
 neighbor 160.89.1.6 filter-list infilter in
```

Route Flap Damping

Stabilising the Network

Route Flap Damping

- Route flap
  - Going up and down of path or change in attribute
    - BGP WITHDRAW followed by UPDATE = 1 flap
    - eBGP neighbour going down/up is NOT a flap
  - Ripples through the entire Internet
  - Wastes CPU
- Damping aims to reduce scope of route flap propagation

Route Flap Damping (Continued)

- Requirements
  - Fast convergence for normal route changes
  - History predicts future behaviour
  - Suppress oscillating routes
  - Advertise stable routes
- Documented in RFC2439

Operation

- Add penalty (1000) for each flap

  Change in attribute gets penalty of 500

- Exponentially decay penalty

  half life determines decay rate

- Penalty above suppress-limit

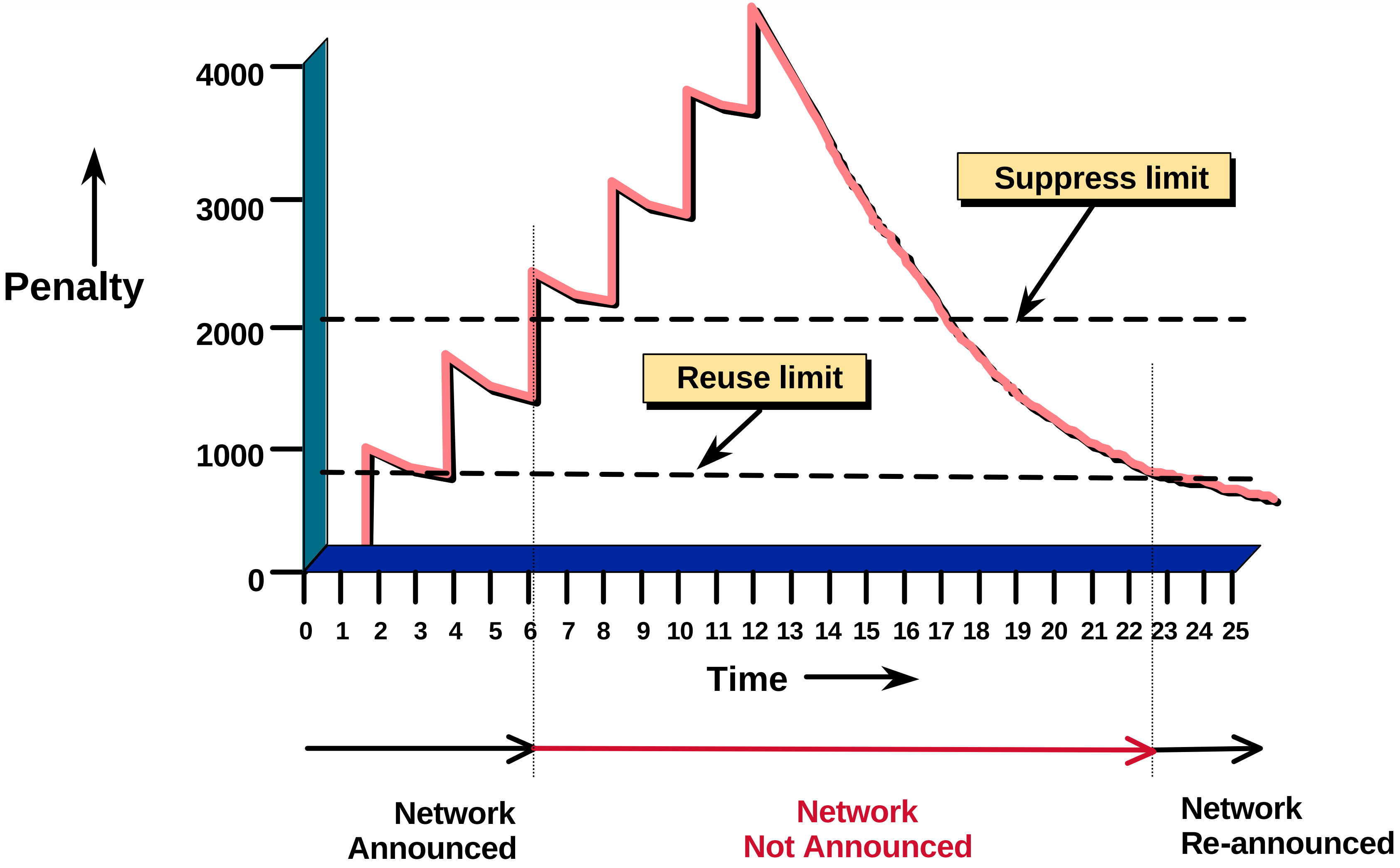
  do not advertise route to BGP peers

- Penalty decayed below reuse-limit

  re-advertise route to BGP peers

  penalty reset to zero when it is half of reuse-limit

Operation


Penalty
4000
3000
2000
1000
0
Suppress limit
Reuse limit
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Time
Network
Announced
Network
Not Announced
Network
Re-announced

Operation

- Only applied to inbound announcements from eBGP peers
- Alternate paths still usable
- Controlled by:

  Half-life (default 15 minutes)

  reuse-limit (default 750)

  suppress-limit (default 2000)

  maximum suppress time (default 60 minutes)

Configuration

Fixed damping

```
router bgp 100
 bgp dampening [<half-life> <reuse-value> <suppress-
  penalty> <maximum suppress time>]
```

Selective and variable damping

```
 bgp dampening [route-map <name>]
```

Variable damping

recommendations for ISPs

http://www.ripe.net/docs/ripe-210.html

Operation

- Care required when setting parameters
- Penalty must be less than reuse-limit at the maximum suppress time
- Maximum suppress time and half life must allow penalty to be larger than suppress limit

Configuration

- Examples - ✗

  ```
  bgp dampening 30 750 3000 60
  ```

  reuse-limit of 750 means maximum possible penalty is 3000 – no prefixes suppressed as penalty cannot exceed suppress-limit

- Examples - ✓

  ```
  bgp dampening 30 2000 3000 60
  ```

  reuse-limit of 2000 means maximum possible penalty is 8000 – suppress limit is easily reached

Maths!

- **Maximum value of penalty is**

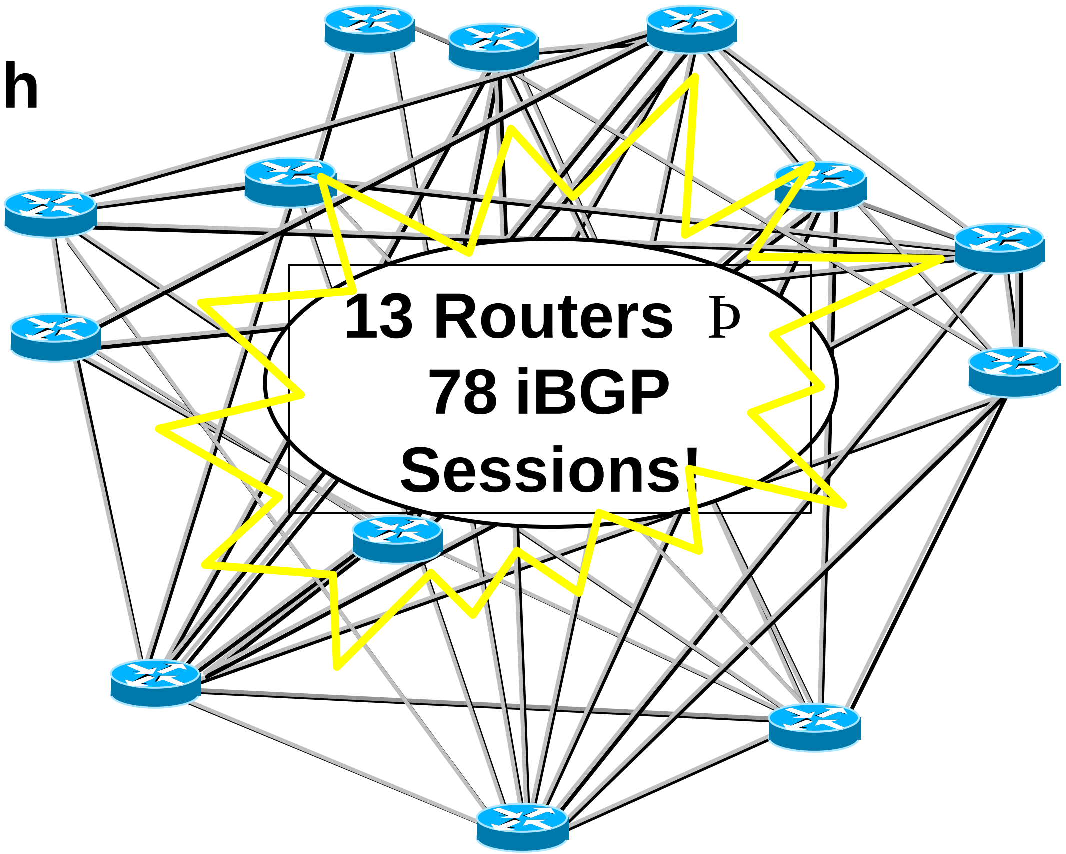
$$\text{max-penalty} = \text{reuse-limit} \times 2^{\left(\frac{\text{max-suppress-time}}{\text{half-life}}\right)}$$

- **Always make sure that suppress-limit is LESS than max-penalty otherwise there will be no flap damping**

Route Reflectors and Confederations

Scaling iBGP mesh

Avoid n(n-1)/2 iBGP mesh



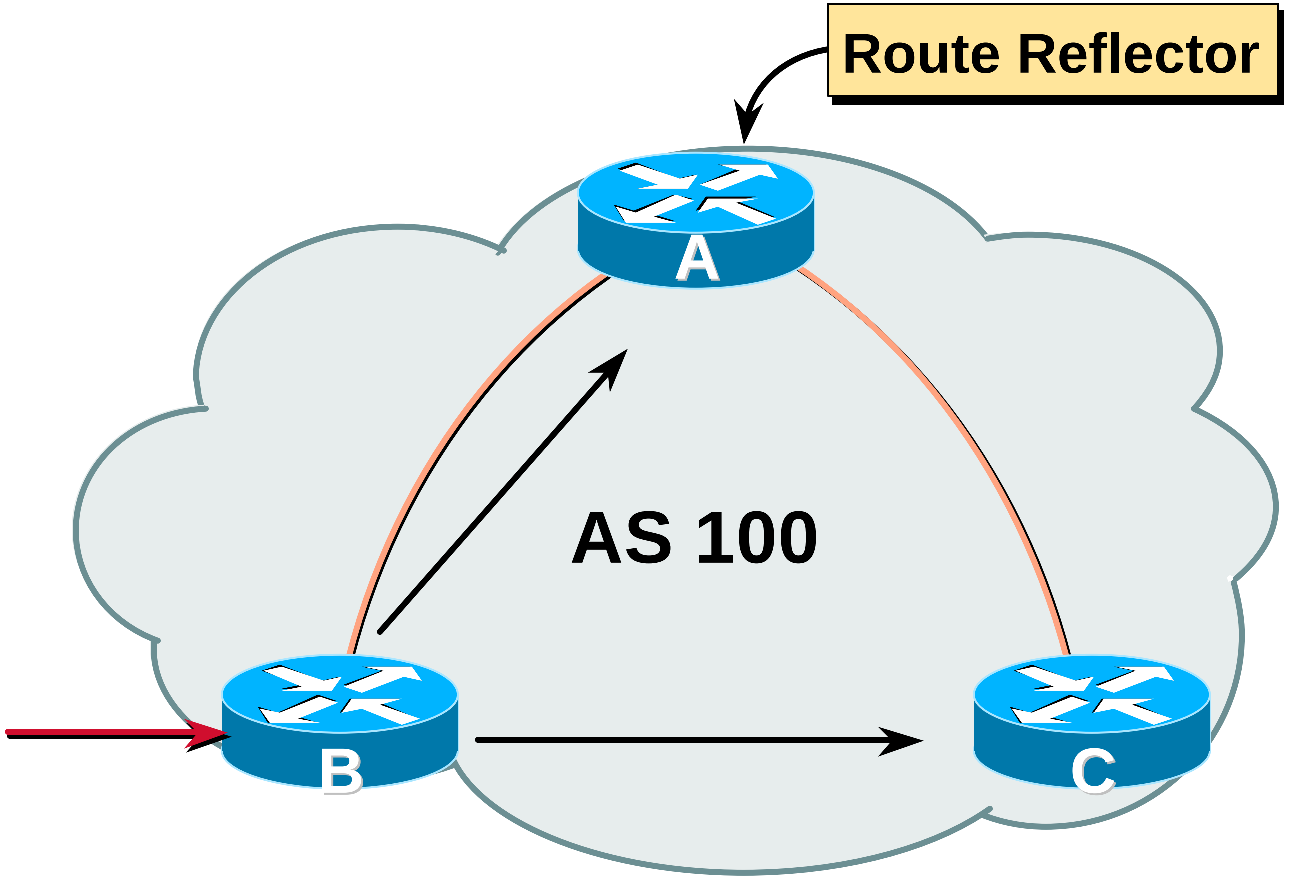
13 Routers Þ 78 iBGP Sessions!

n=1000 Þ nearly half a million ibgp sessions!

Two solutions

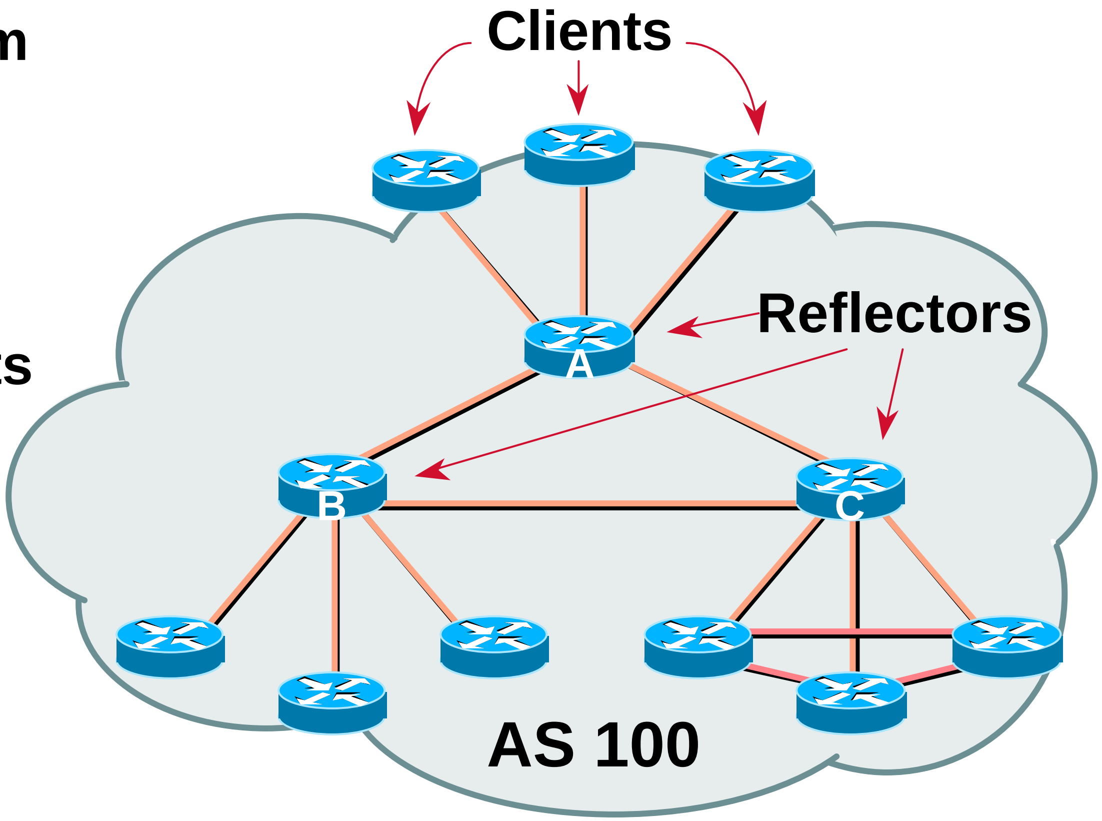
- Route reflector – simpler to deploy and run
- Confederation – more complex, corner case benefits

Route Reflector: Principle



Route Reflector

- Reflector receives path from clients and non-clients
- Selects best path
- If best path is from client, reflect to other clients and non-clients
- If best path is from non-client, reflect to clients only
- Non-meshed clients
- Described in RFC2796



Route Reflector Topology

- Divide the backbone into multiple clusters
- At least one route reflector and few clients per cluster
- Route reflectors are fully meshed
- Clients in a cluster could be fully meshed
- Single IGP to carry next hop and local routes

Route Reflectors: Loop Avoidance

- Originator_ID attribute

  Carries the RID of the originator of the route in the local AS (created by the RR)

- Cluster_list attribute

  The local cluster-id is added when the update is sent by the RR

  Cluster-id is automatically set from router-id (address of loopback)

  Do NOT use *bgp cluster-id x.x.x.x*

Route Reflectors: Redundancy

- **Multiple RRs can be configured in the same cluster – not advised!**

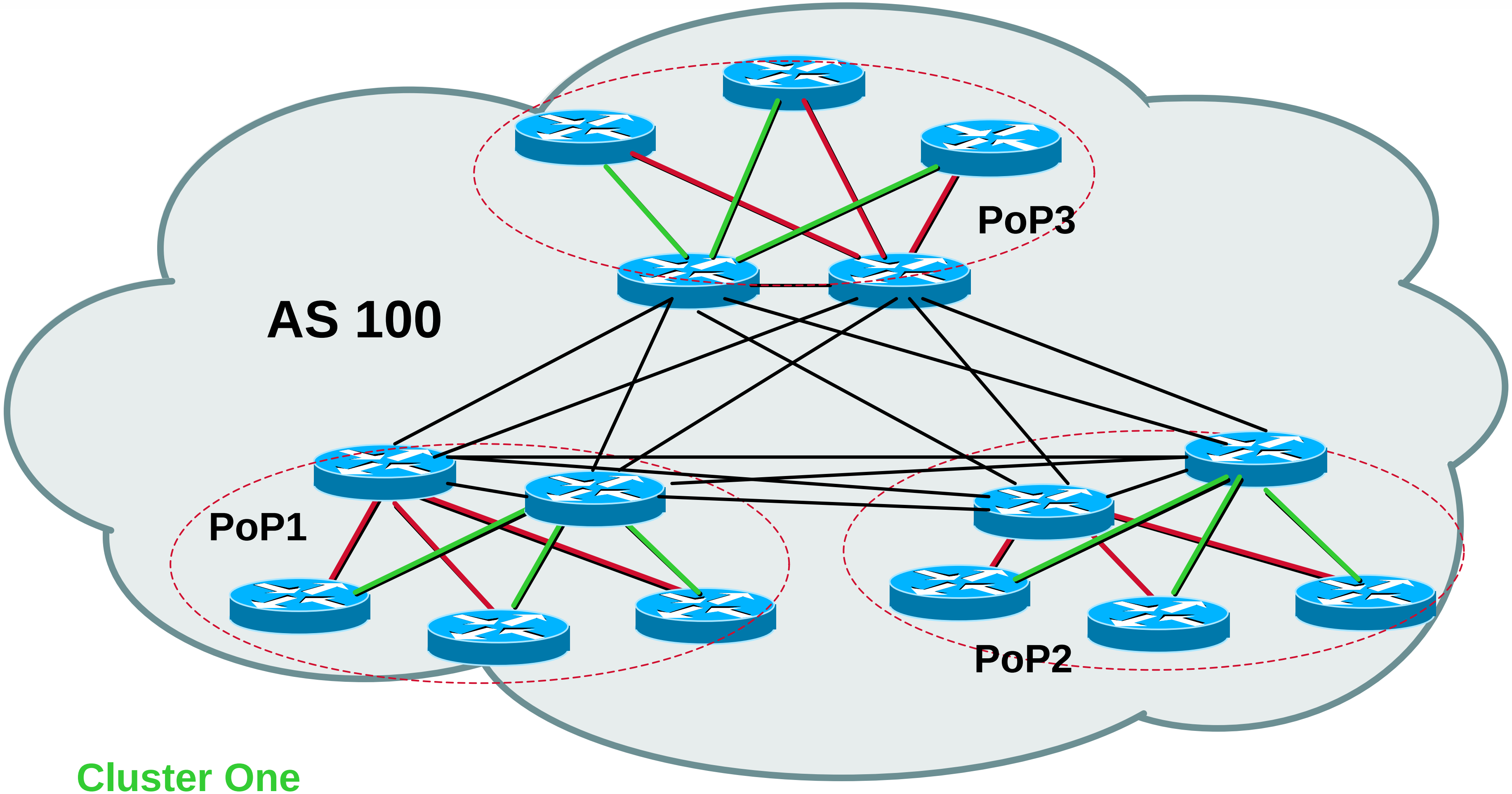
  All RRs in the cluster must have the same cluster-id (otherwise it is a different cluster)

- **A router may be a client of RRs in different clusters**

  Common today in ISP networks to overlay two clusters – redundancy achieved that way

  ® Each client has two RRs = redundancy

Route Reflectors: Redundancy



Cluster One

Cluster Two

Route Reflectors: Migration

- Where to place the route reflectors?

  Always follow the physical topology!

  This will guarantee that the packet forwarding won’t be affected

- Typical ISP network:

  PoP has two core routers

  Core routers are RR for the PoP

  Two overlaid clusters

Route Reflectors: Migration

- Typical ISP network:

  Core routers have fully meshed iBGP

  Create further hierarchy if core mesh too big

    Split backbone into regions

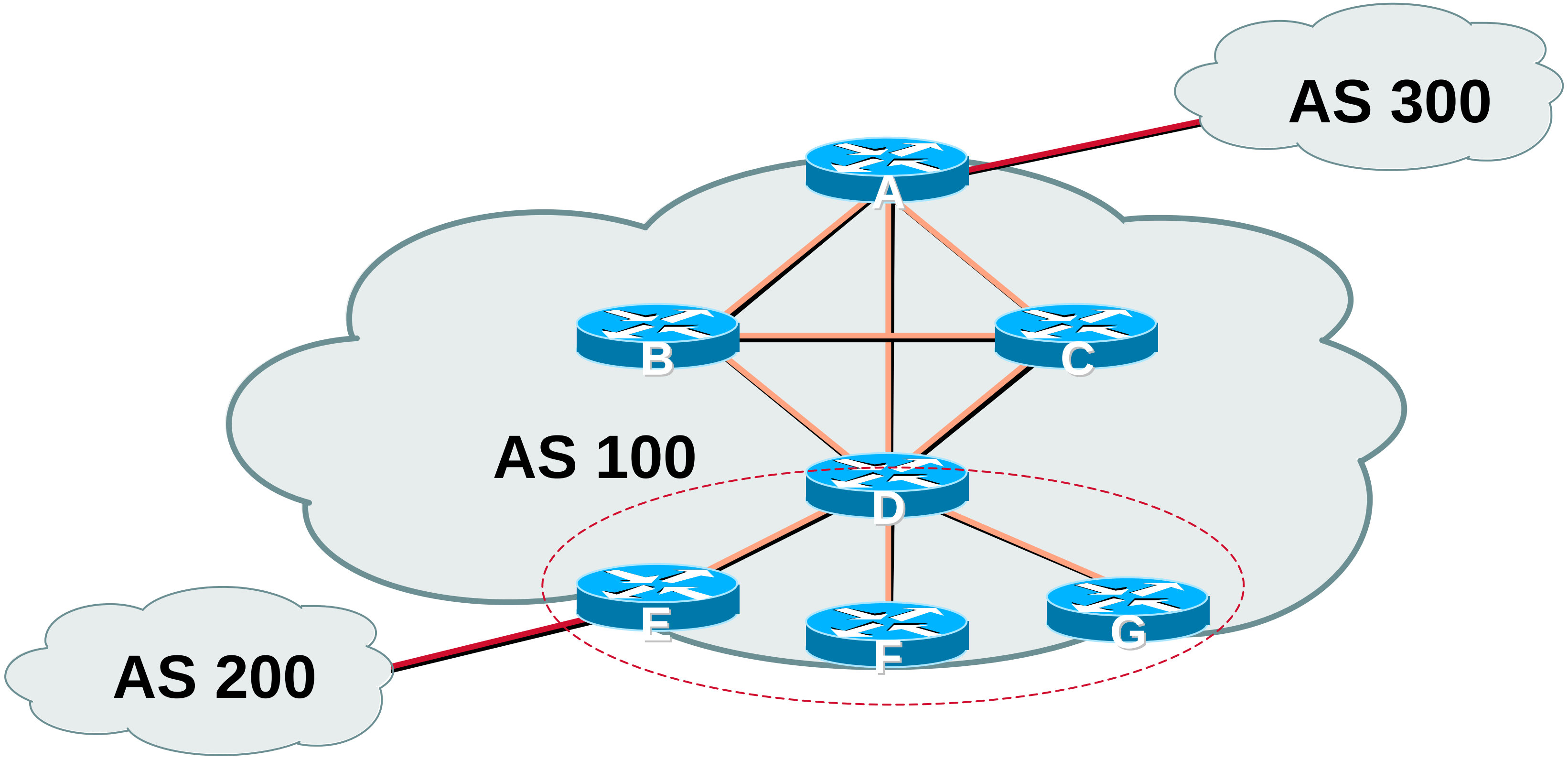
- Configure one cluster pair at a time

  Eliminate redundant iBGP sessions

  Place maximum one RR per cluster

  Easy migration, multiple levels

Route Reflector: Migration



- **Migrate small parts of the network, one part at a time.**

Configuring a Route Reflector

```
router bgp 100
 neighbor 1.1.1.1 remote-as 100
 neighbor 1.1.1.1 route-reflector-client
 neighbor 2.2.2.2 remote-as 100
 neighbor 2.2.2.2 route-reflector-client
 neighbor 3.3.3.3 remote-as 100
 neighbor 3.3.3.3 route-reflector-client
```

Confederations

- Divide the AS into sub-AS
  - eBGP between sub-AS, but some iBGP information is kept
    - Preserve NEXT_HOP across the sub-AS (IGP carries this information)
    - Preserve LOCAL_PREF and MED
- Usually a single IGP
- Described in RFC3065

Confederations (Cont.)

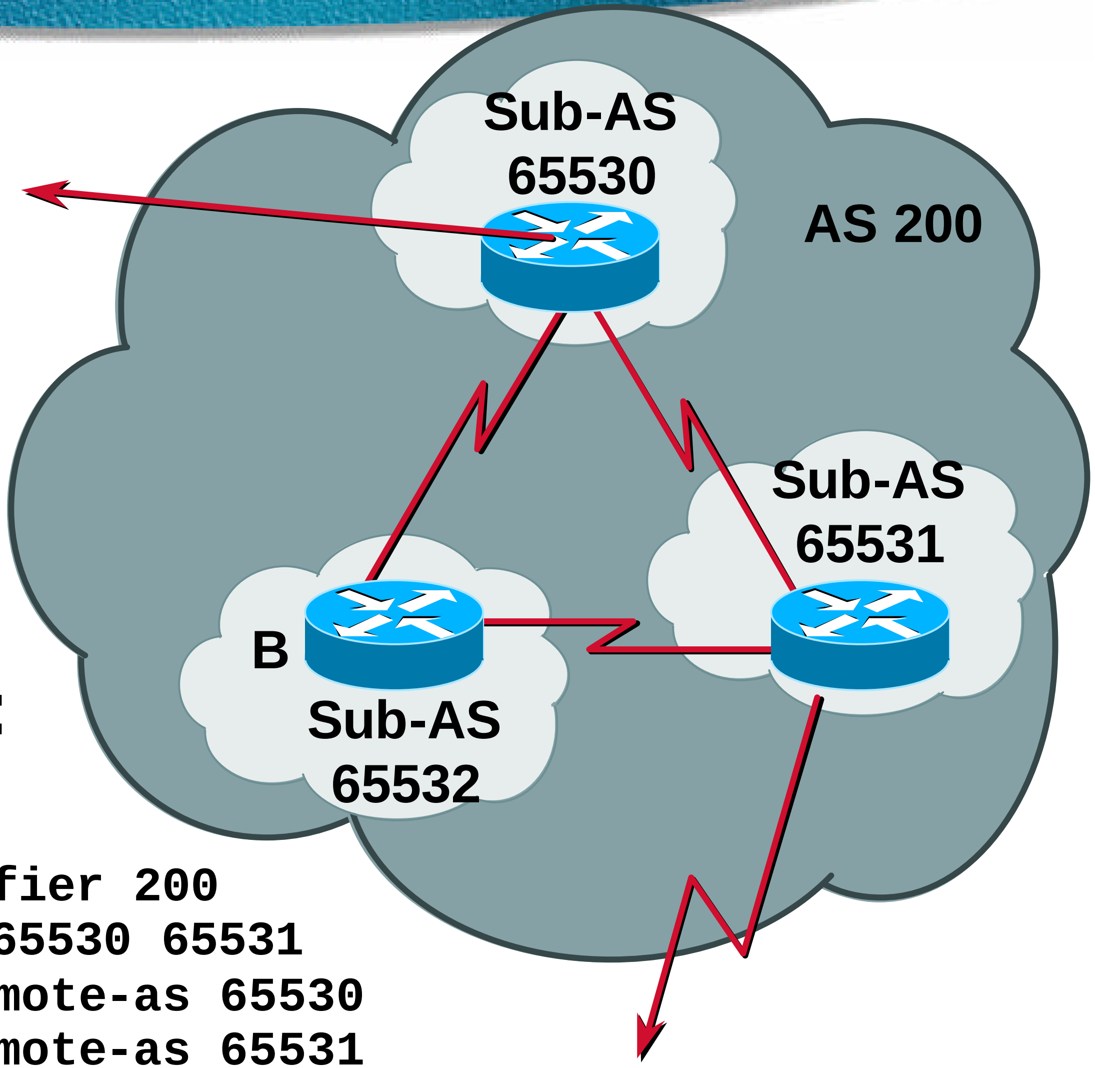
- **Visible to outside world as single AS – "Confederation Identifier"**

  Each sub-AS uses a number from the private space (64512-65534)

- **iBGP speakers in sub-AS are fully meshed**

  The total number of neighbors is reduced by limiting the full mesh requirement to only the peers in the sub-AS

Confederations (cont.)



- **Configuration (rtr B):**

```
router bgp 65532
 bgp confederation identifier 200
 bgp confederation peers 65530 65531
 neighbor 141.153.12.1 remote-as 65530
 neighbor 141.153.17.2 remote-as 65531
```

Route Propagation Decisions

- Same as with “normal” BGP:
  - From peer in same sub-AS → only to external peers
  - From external peers → to all neighbors
- “External peers” refers to
  - Peers outside the confederation
  - Peers in a different sub-AS
    - Preserve LOCAL_PREF, MED and NEXT_HOP

Confederations (cont.)

- Example (cont.):

```
BGP table version is 78, local router ID is 141.153.17.1

Status codes: s suppressed, d damped, h history, * valid, >
best, i - internal

Origin codes: i - IGP, e - EGP, ? - incomplete

Network         Next Hop      Metric LocPrf Weight Path

*> 10.0.0.0     141.153.14.3   0     100       0    (65531) 1 i

*> 141.153.0.0 141.153.30.2   0     100       0    (65530) i

*> 144.10.0.0  141.153.12.1   0     100       0    (65530) i

*> 199.10.10.0 141.153.29.2   0     100       0    (65530) 1 i
```

RRs or Confederations

	Internet Connectivity	Multi-Level Hierarchy	Policy Control	Scalability	Migration Complexity
Confederations	Anywhere in the Network	Yes	Yes	Medium	Medium to High
Route Reflectors	Anywhere in the Network	Yes	Yes	Very High	Very Low

Most new service provider networks now deploy Route Reflectors from Day One

More points about confederations

- Can ease “absorbing” other ISPs into you ISP – e.g., if one ISP buys another (can use local-as feature to do a similar thing)
- You can use route-reflectors with confederation sub-AS to reduce the sub-AS iBGP mesh

BGP Scaling Techniques

- These 4 techniques should be core requirements in all ISP networks

  Soft reconfiguration/Route Refresh

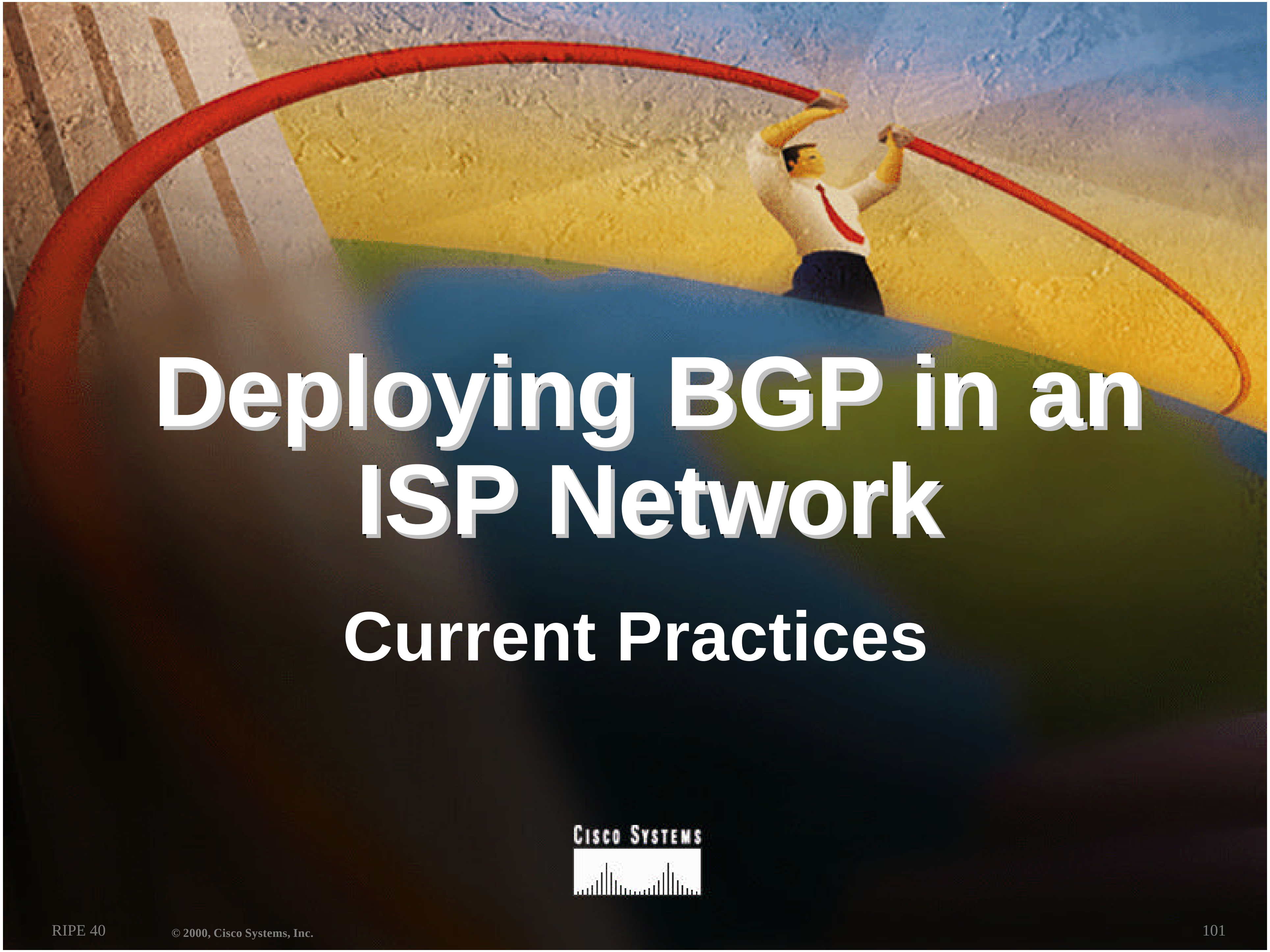
  Peer groups

  Route flap damping

  Route reflectors

BGP for Internet Service Providers

- BGP Basics (quick recap)
- Scaling BGP
- Deploying BGP in an ISP network
- Trouble & Troubleshooting
- Multihoming Examples
- Using Communities



Deploying BGP in an ISP Network

Current Practices

BGP versus OSPF/ISIS

- Internal Routing Protocols (IGPs)

  examples are ISIS and OSPF

  used for carrying infrastructure addresses

  NOT used for carrying Internet prefixes or customer prefixes

  design goal is to minimise number of prefixes in IGP to aid scalability and rapid convergence

BGP versus OSPF/ISIS

- BGP used internally (iBGP) and externally (eBGP)
- iBGP used to carry
  - some/all Internet prefixes across backbone
  - customer prefixes
- eBGP used to
  - exchange prefixes with other ASes
  - implement routing policy

BGP versus OSPF/ISIS Configuration Example

```
router bgp 34567
 neighbor core-ibgp peer-group
 neighbor core-ibgp remote-as 34567
 neighbor core-ibgp update-source Loopback0
 neighbor core-ibgp send-community
 neighbor core-ibgp-partial peer-group
 neighbor core-ibgp-partial remote-as 34567
 neighbor core-ibgp-partial update-source Loopback0
 neighbor core-ibgp-partial send-community
 neighbor core-ibgp-partial prefix-list network-ibgp out
 neighbor 222.1.9.10 peer-group core-ibgp
 neighbor 222.1.9.13 peer-group core-ibgp-partial
 neighbor 222.1.9.14 peer-group core-ibgp-partial
```

BGP versus OSPF/ISIS

- DO NOT:

  distribute BGP prefixes into an IGP

  distribute IGP routes into BGP

  use an IGP to carry customer prefixes

- YOUR NETWORK WILL NOT SCALE

Aggregation

Quality or Quantity?

Aggregation

- ISPs receive address block from Regional Registry or upstream provider
- Aggregation means announcing the address block only, not subprefixes

  Subprefixes should only be announced in special cases – see later.

- Aggregate should be generated internally

  Not on the network borders!

Configuring Aggregation – Method One

- ISP has 221.10.0.0/19 address block
- To put into BGP as an aggregate:

```
router bgp 100
 network 221.10.0.0 mask 255.255.224.0
ip route 221.10.0.0 255.255.224.0 null0
```

- The static route is a “pull up” route

  more specific prefixes within this address block ensure connectivity to ISP’s customers

  “longest match lookup”

Configuring Aggregation – Method Two

- Configuration Example

```
router bgp 109
 network 221.10.0.0 mask 255.255.252.0
 aggregate-address 221.10.0.0 255.255.224.0 [summary-only]
```

- Requires more specific prefix in routing table before aggregate is announced
- {summary-only} keyword

  ensures that only the summary is announced if a more specific prefix exists in the routing table

- Sets “aggregator” attribute

  Useful for debugging

Announcing Aggregate – Cisco IOS

- **Configuration Example**

```
router bgp 100
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.1 remote-as 101
 neighbor 222.222.10.1 prefix-list out-filter out
!
ip route 221.10.0.0 255.255.224.0 null0
!
ip prefix-list out-filter permit 221.10.0.0/19
```

Announcing an Aggregate

- ISPs who don’t and won’t aggregate are held in poor regard by community
- Registries’ minimum allocation size is now a /20

  no real reason to see subprefixes of allocated blocks in the Internet

  BUT there are currently >60000 /24s!

Receiving Prefixes

Receiving Prefixes from downstream peers

- ISPs should only accept prefixes which have been assigned or allocated to their downstream peer
- For example

  downstream has 220.50.0.0/20 block

  should only announce this to peers

  peers should only accept this from them

Receiving Prefixes – Cisco IOS

- Configuration Example on upstream

```
router bgp 100
 neighbor 222.222.10.1 remote-as 101
 neighbor 222.222.10.1 prefix-list customer in
!
ip prefix-list customer permit 220.50.0.0/20
```

Receiving Prefixes from upstream peers

- Not desirable unless really necessary

  special circumstances – see later

- Ask upstream to either:

  originate a default-route

  -or-

  announce one prefix you can use as default

Receiving Prefixes from upstream peers

- Downstream Router Configuration

```
router bgp 100
 network 221.10.0.0 mask 255.255.224.0
 neighbor 221.5.7.1 remote-as 101
 neighbor 221.5.7.1 prefix-list infilter in
 neighbor 221.5.7.1 prefix-list outfilter out
!
ip prefix-list infilter permit 0.0.0.0/0
!
ip prefix-list outfilter permit 221.10.0.0/19
```

Receiving Prefixes from upstream peers

- Upstream Router Configuration

```
router bgp 101
 neighbor 221.5.7.2 remote-as 100
 neighbor 221.5.7.2 default-originate
 neighbor 221.5.7.2 prefix-list cust-in in
 neighbor 221.5.7.2 prefix-list cust-out out
!
ip prefix-list cust-in permit 221.10.0.0/19
!
ip prefix-list cust-out permit 0.0.0.0/0
```

Receiving Prefixes from upstream peers

- If necessary to receive prefixes from upstream provider, care is required
  - don’t accept RFC1918 etc prefixes
    - http://www.ietf.org/internet-drafts/draft-manning-dsua-06.txt
  - don’t accept your own prefix
  - don’t accept default (unless you need it)
  - don’t accept prefixes longer than /24
    - This guideline may change “soon”

Receiving Prefixes

```
router bgp 100
 network 221.10.0.0 mask 255.255.224.0
 neighbor 221.5.7.1 remote-as 101
 neighbor 221.5.7.1 prefix-list in-filter in
!
ip prefix-list in-filter deny 0.0.0.0/0           ! Block default
ip prefix-list in-filter deny 0.0.0.0/8 le 32
ip prefix-list in-filter deny 10.0.0.0/8 le 32
ip prefix-list in-filter deny 127.0.0.0/8 le 32
ip prefix-list in-filter deny 169.254.0.0/16 le 32
ip prefix-list in-filter deny 172.16.0.0/12 le 32
ip prefix-list in-filter deny 192.0.2.0/24 le 32
ip prefix-list in-filter deny 192.168.0.0/16 le 32
ip prefix-list in-filter deny 221.10.0.0/19 le 32 ! Block local prefix
ip prefix-list in-filter deny 224.0.0.0/3 le 32   ! Block multicast
ip prefix-list in-filter deny 0.0.0.0/0 ge 25     ! Block prefixes >/24
ip prefix-list in-filter permit 0.0.0.0/0 le 32
```

Prefixes into iBGP

Injecting prefixes into iBGP

- Use iBGP to carry customer prefixes

  don’t ever use IGP

- Point static route to customer interface
- Use BGP network statement
- As long as static route exists (interface active), prefix will be in BGP

Router Configuration network statement

- **Example:**

```
interface loopback 0
 ip address 215.17.3.1 255.255.255.255
!
interface Serial 5/0
 ip unnumbered loopback 0
 ip verify unicast reverse-path
!
ip route 215.34.10.0 255.255.252.0 Serial 5/0
!
router bgp 100
 network 215.34.10.0 mask 255.255.252.0
```

Injecting prefixes into iBGP

- interface flap will result in prefix withdraw and re-announce

  use “ip route…permanent”

  Static route always exists, even if interface is down ® prefix announced in iBGP

- many ISPs use redistribute static rather than network statement

  only use this if you understand why

Inserting prefixes into BGP – redistribute static

- Care required with redistribute!

  redistribute <routing-protocol> means everything in the <routing-protocol> will be transferred into the current routing protocol

  Does not scale if uncontrolled

  Best avoided if at all possible

  redistribute normally used with “route-maps” and under tight administrative control

Router Configuration redistribute static

- Example:

```
ip route 215.34.10.0 255.255.252.0 Serial 5/0
!
router bgp 100
 redistribute static route-map static-to-bgp
<snip>
!
route-map static-to-bgp permit 10
 match ip address prefix-list ISP-block
 set origin igp
<snip>
!
ip prefix-list ISP-block permit 215.34.10.0/22 le 30
!
```

Injecting prefixes into iBGP

- Route-map ISP-block can be used for many things:

  setting communities and other attributes

  setting origin code to IGP, etc

- Be careful with prefix-lists and route-maps

  absence of either/both could mean all statically routed prefixes go into iBGP

Configuration Tips

iBGP and IGPs

- Make sure loopback is configured on router

  iBGP between loopbacks, NOT real interfaces

- Make sure IGP carries loopback /32 address

- Make sure IGP carries DMZ nets

  Use ip-unnumbered where possible

  Or use next-hop-self on iBGP neighbours

  neighbor x.x.x.x next-hop-self

Next-hop-self

- Used by many ISPs on edge routers

  Preferable to carrying DMZ /30 addresses in the IGP

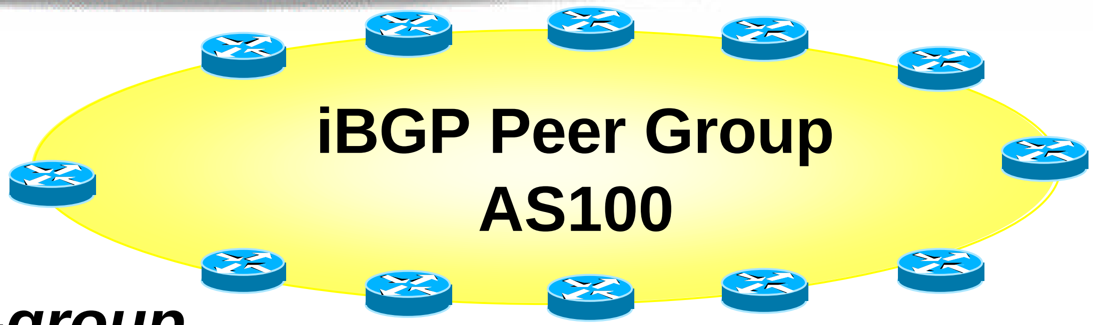
  Reduces size of IGP to just core infrastructure

  Alternative to using ip unnumbered

  Helps scale network

  BGP speaker announces external network using local address (loopback) as next-hop

BGP Template – iBGP peers



```
router bgp  100
neighbor internal peer-group
neighbor internal description ibgp peers
neighbor internal remote-as 100
neighbor internal update-source Loopback0
neighbor internal next-hop-self
neighbor internal send-community
neighbor internal version 4
neighbor internal password 7 03085A09
neighbor 1.0.0.1 peer-group internal
neighbor 1.0.0.2 peer-group internal
```

BGP Template – iBGP peers

- Use peer-groups
- iBGP between loopbacks!
- Next-hop-self

  Keep DMZ and point-to-point out of IGP
- Always send communities in iBGP

  Otherwise accidents will happen
- Hardwire BGP to version 4

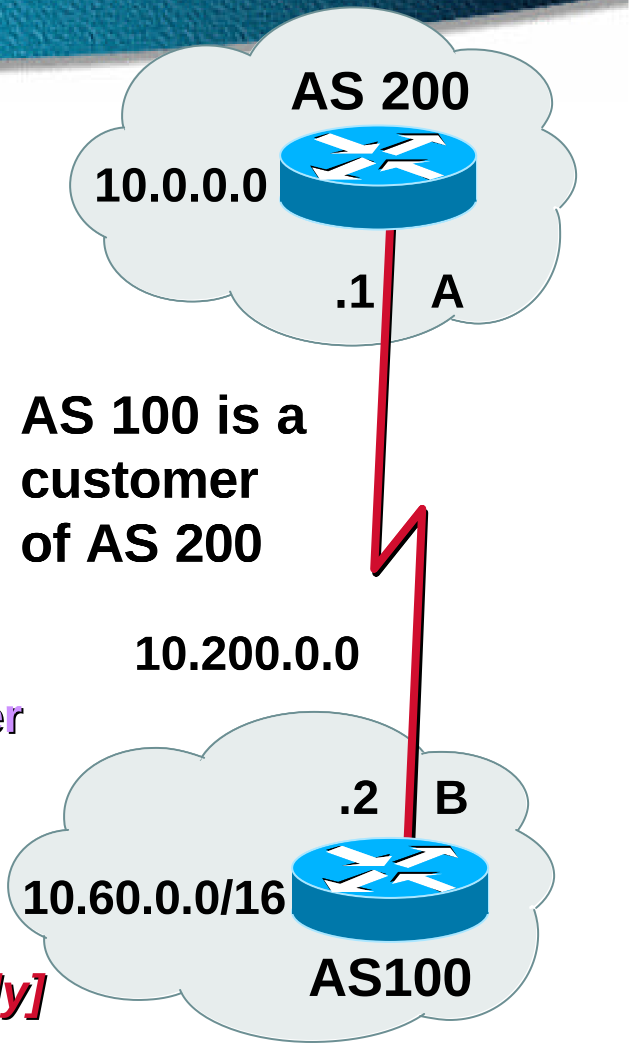
  Yes, this is being paranoid!
- Use passwords on iBGP session

  Not being paranoid, VERY necessary

BGP Template – eBGP peers

Router B:

```
router bgp 100
bgp dampening route-map RIPE-210-flap
network 10.60.0.0 mask 255.255.0.0
neighbor external peer-group
neighbor external remote-as 200
neighbor external description ISP connection
neighbor external remove-private-AS
neighbor external version 4
neighbor external prefix-list ispout out ; “accident” filter
neighbor external route-map ispout out ; “real” filter
neighbor external route-map ispin in
neighbor external password 7 020A0559
neighbor external maximum-prefix 120000 [warning-only]
neighbor 10.200.0.1 peer-group external
ip route 10.60.0.0 255.255.0.0 null0 254
```



AS 100 is a customer of AS 200

BGP Template – eBGP peers

- BGP damping – use RIPE-210 parameters
- Remove private ASes from announcements

  Common omission today
- Use extensive filters, with “backup”
- Use password agreed between you and peer on eBGP session
- Use maximum-prefix tracking

  Router will warn you if there are sudden changes in BGP table size, bringing down eBGP if necessary

More BGP “defaults”

- Log neighbour changes

  bgp log-neighbor-changes

- Enable deterministic MED

  bgp deterministic-med

  Otherwise bestpath could be different every time BGP session is reset

- Make BGP admin distance higher than any IGP

  distance bgp 200 200 200

Customer Aggregation

- BGP customers

  Offer max 3 types of feeds (easier than custom configuration per peer)

  Use communities

- Static customers

  Use communities

- Differentiate between different types of prefixes

  Makes eBGP filtering easy

BGP Customer Aggregation Guidelines

- Define at least three peer groups:

  cust-default—send default route only

  cust-cust—send customer routes only

  cust-full —send full Internet routes

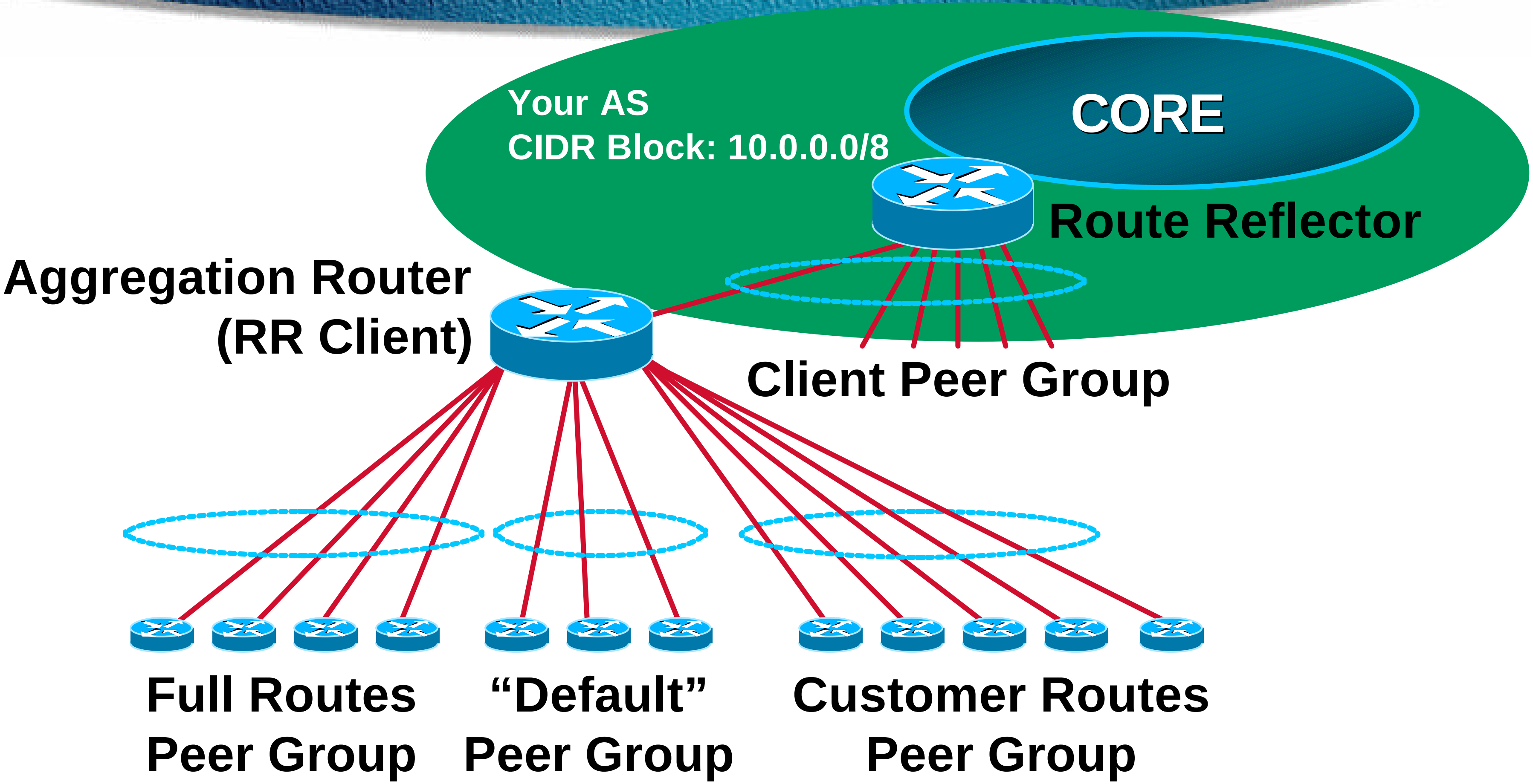
- Identify routes via communities e.g.

  100:4100=customers; 100:4500=peers

- Apply passwords per neighbour

- Apply inbound & outbound prefix-list per neighbour

BGP Customer Aggregation



Apply passwords and in/outbound prefix-list directly to each neighbour

Static Customer Aggregation Guidelines

- Identify routes via communities, e.g.

  100:4000=my address blocks

  100:4200=customers from my block

  100:4300=customers outside my block

  Helps with aggregation, iBGP, filtering

- BGP network statements on aggregation routers set correct community

Sample core configuration

- eBGP peers and upstreams

  Send communities 100:4000, 100:4100 and 100:4300, receive everything

- iBGP full routes

  Send everything (only network core)

- iBGP partial routes

  Send communities 100:4000, 100:4100, 100:4200, 100:4300 and 100:4500 (edge routers, peering routers, IXP routers)

- Simple configuration with peer-groups and route-maps

Acquisitions!

- **Your ISP has just bought another ISP**

  How to merge networks?

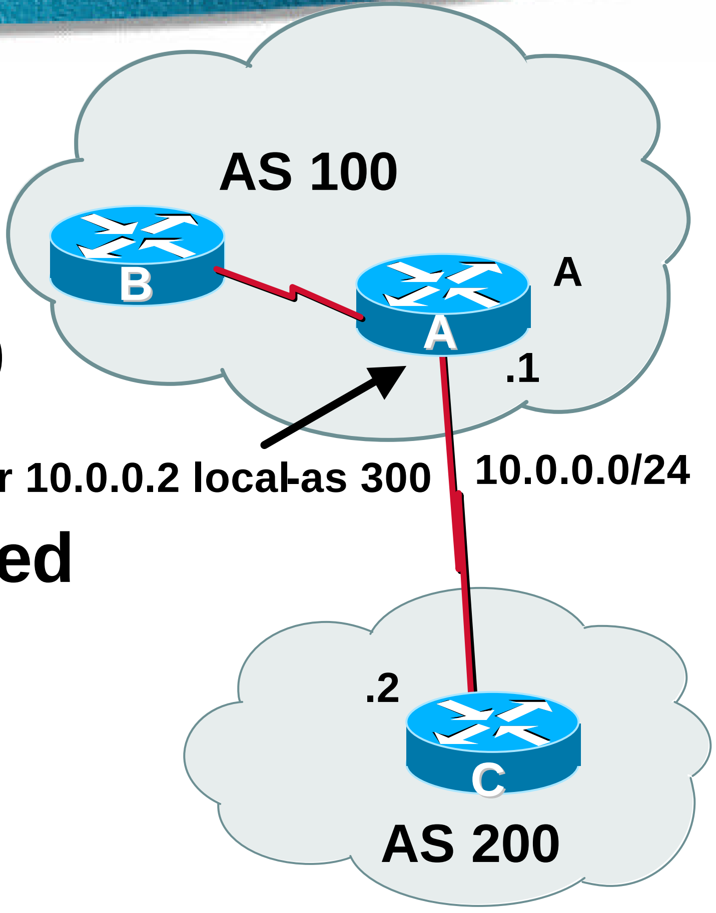
- **Options:**

  use confederations – make their AS a sub-AS (only useful if you are using confederations already)

  use the BGP local-as feature to implement a gradual transition – overrides BGP process ID

  neighbor *x.x.x.x* local-as *as-number*

local-AS – Application



- **Router A has a process ID of 100**
- **The peering with AS200 is established as if router A belonged to AS300.**
- **AS_PATH**

  routes originated in AS100 = 300 100

  routes received from AS200 = 300 200

BGP for Internet Service Providers

- BGP Basics (quick recap)
- Scaling BGP
- Deploying BGP in an ISP network
- Trouble & Troubleshooting
- Multihoming Examples
- Using Communities

Troubleshooting

Staying out of Trouble

Cisco Systems

Potential Caveats and Operational Problems

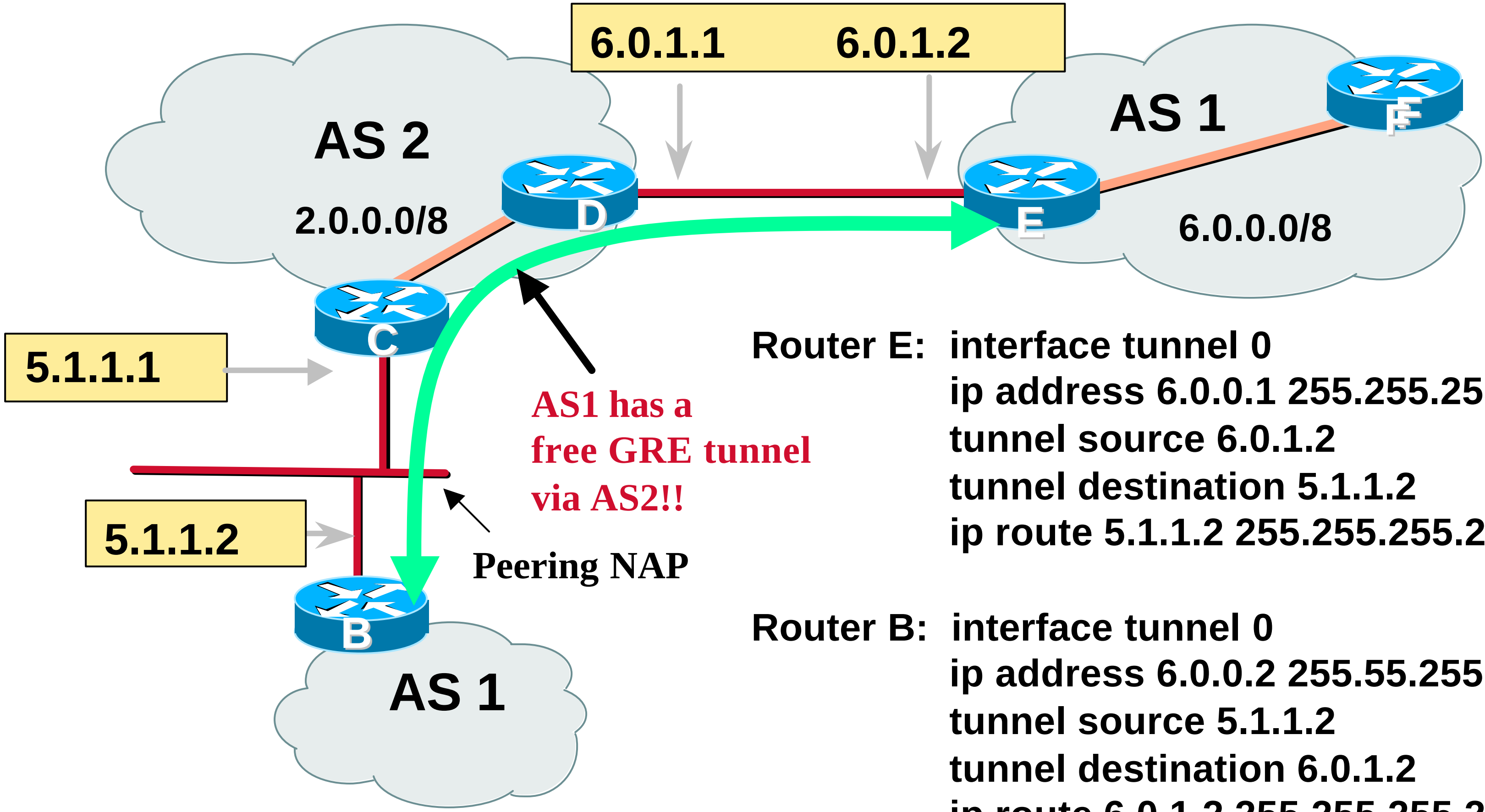
- GRE Tunnels & IXPs
- Archaic Features

  Auto-summarisation & synchronisation
- Route Reflectors

  Follow the topology
- Common Problems

  …and the solutions!

Prevent GRE VPNs



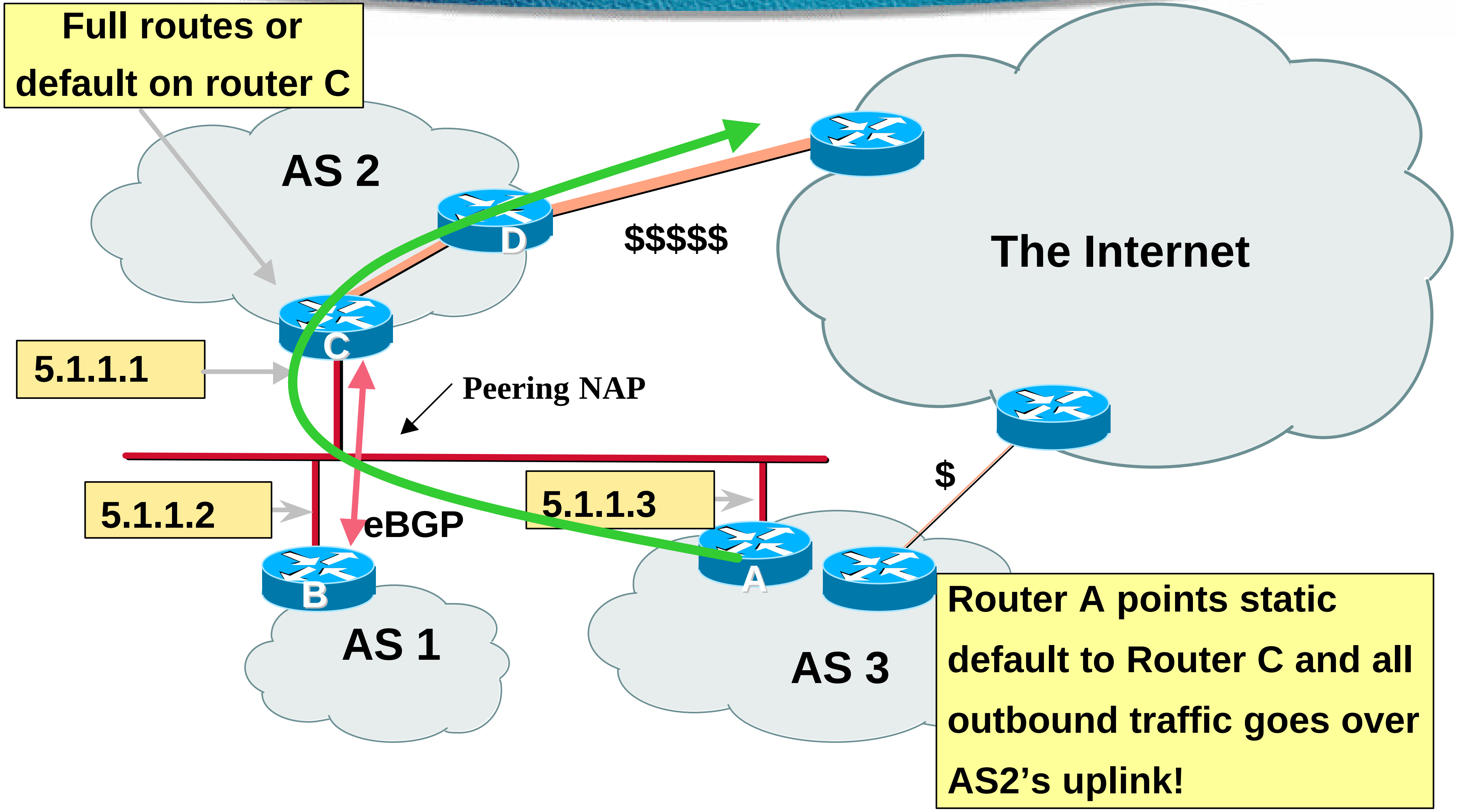
AS1 has a free GRE tunnel via AS2!!

```
Router E:  interface tunnel 0
           ip address 6.0.0.1 255.255.255.252
           tunnel source 6.0.1.2
           tunnel destination 5.1.1.2
           ip route 5.1.1.2 255.255.255.255 6.0.1.1

Router B:  interface tunnel 0
           ip address 6.0.0.2 255.55.255.252
           tunnel source 5.1.1.2
           tunnel destination 6.0.1.2
           ip route 6.0.1.2 255.255.255.255 5.1.1.1
```

Don’t carry IXP net in your IGP – use next-hop-self!

Prevent "Defaulting"



Full routes or default on router C

Router A points static default to Router C and all outbound traffic goes over AS2's uplink!

Watch out at IXPs/NAPs

- IXP router should not carry full routes or have a default
- ISP should not carry IXP/NAP network prefix internally

  Use BGP next-hop-self

- or -

- Use RPF check for non-peers
- Use good filters for peers

Auto Summarisation – Cisco IOS

- Archaic feature
- Automatically summarises subprefixes to the classful network for prefixes redistributed into BGP

  Example:

  ```
  61.10.8.0/22 ® 61.0.0.0/8
  ```

- Must be turned off for any Internet connected site using BGP.

  ```
  router bgp 109
   no auto-summary
  ```

Synchronisation – Cisco IOS

- **Archaic feature**
- **BGP will not advertise a route before all routers in the AS have learned it via an IGP**
- **Disable synchronisation if:**

  AS doesn’t pass traffic from one AS to another, or

  All transit routers in AS run BGP, or

  iBGP is used across backbone

```
router bgp 109
 no synchronization
```

Troubleshooting

Common Problems and their Solutions

Troubleshooting – Examples

- Missing routes
- Route Oscillation
- Routing Loops
- Troubleshooting hints

Route Origination

- Network statement with mask

```
R1# show run | begin bgp
 network 200.200.0.0 mask 255.255.252.0
```

- BGP is not originating the route???

```
R1# show ip bgp | include 200.200.0.0
R1#
```

- Do we have the *exact* route?

```
R1# show ip route 200.200.0.0 255.255.252.0
% Network not in table
```

Route Origination

- Nail down routes you want to originate

```
R1#ip route 200.200.0.0 255.255.252.0 Null0 200
```

- Check the RIB

```
R1# show ip route 200.200.0.0 255.255.252.0
       200.200.0.0/22 is subnetted, 1 subnets
S     200.200.0.0 [1/0] via Null 0
```

- BGP originates the route!!

```
R1# show ip bgp | include 200.200.0.0
*> 200.200.0.0/22    0.0.0.0          0    32768
```

Route Oscillation

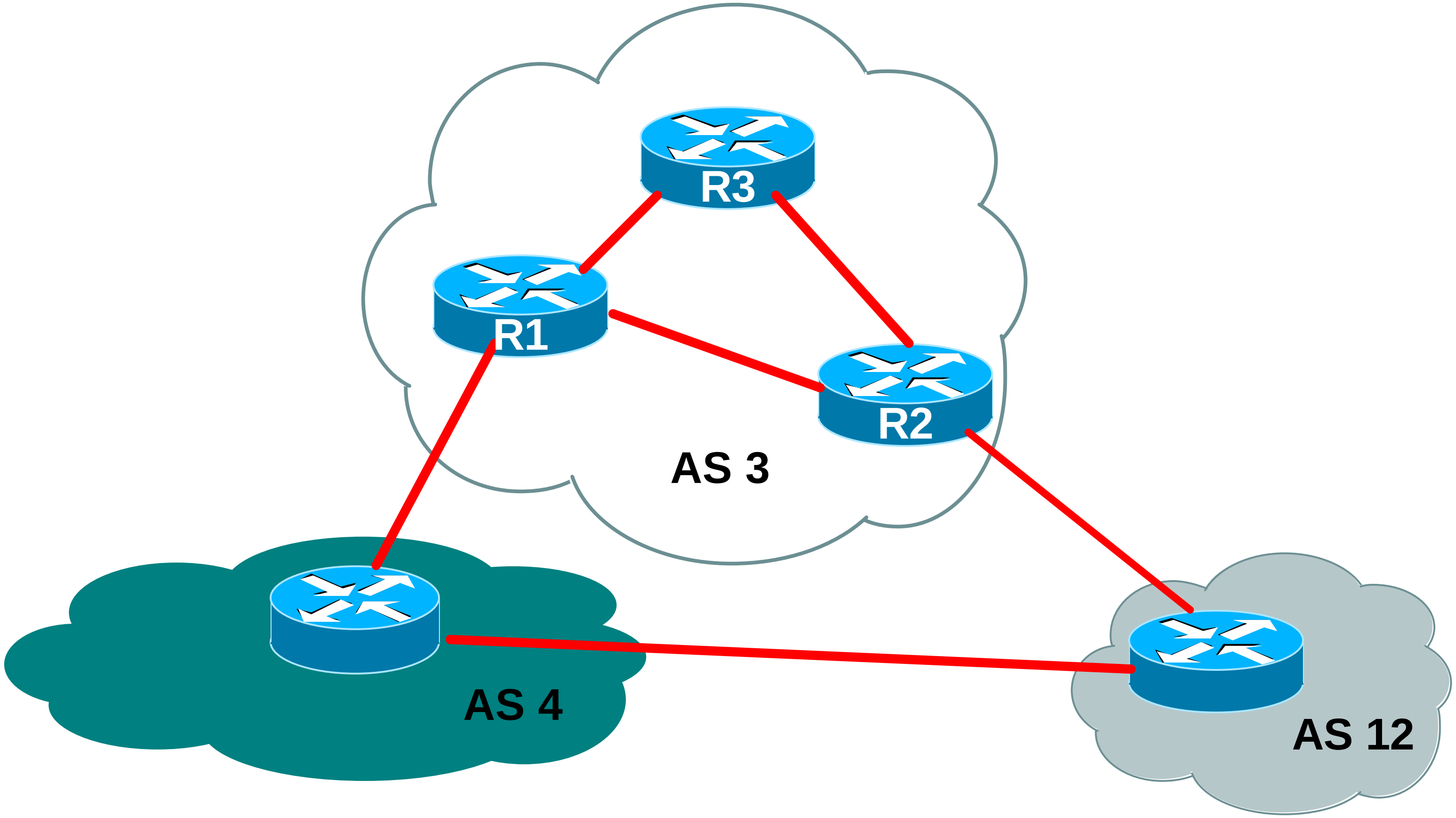
- **One of the most common problems!**

  Every minute routes flap in the routing table from one next hop to another

  With large routing table the most obvious symptom is high CPU in the “BGP-Router” process

  Can be frustrating to track down unless you have seen it before!

Route Oscillation – Diagram



Route Oscillation – Symptom

```
R3#show ip bgp summary
BGP router identifier 3.3.3.3, local AS number 3
BGP table version is 502, main routing table version 502
267 network entries and 272 paths using 34623 bytes of memory
…
R3#sh ip route summary | begin bgp
bgp 3           4           6               520         1400
  External: 0 Internal: 10 Local: 0
internal        5                                           5800
Total           10          263         13936       43320
```

- **Watch for:**

  table version number incrementing rapidly

  number of networks/paths or external/internal routes changing.

Route Oscillation – Troubleshooting

Pick up a bgp route from the RIB that is less than a minute old and watch what happens with the routing/bgp table …

```
R3#show ip route 156.1.0.0
Routing entry for 156.1.0.0/16
  Known via "bgp 3", distance 200, metric 0
 Routing Descriptor Blocks:
  * 1.1.1.1, from 1.1.1.1, 00:00:53 ago
      Route metric is 0, traffic share count is 1
      AS Hops 2, BGP network version 474

R3#show ip bgp 156.1.0.0
BGP routing table entry for 156.1.0.0/16, version 474
Paths: (2 available, best #1)
  Advertised to non peer-group peers:
    2.2.2.2
  4 12
    1.1.1.1 from 1.1.1.1 (1.1.1.1)
      Origin IGP, localpref 100, valid, internal, best
  12
    142.108.10.2 (inaccessible) from 2.2.2.2 (2.2.2.2)
      Origin IGP, metric 0, localpref 100, valid, internal
```

Route Oscillation – Troubleshooting

…and after bgp_scanner runs (by default once a minute):

```
R3#sh ip route 156.1.0.0
Routing entry for 156.1.0.0/16
  Known via "bgp 3", distance 200, metric 0
    Routing Descriptor Blocks:
  * 142.108.10.2, from 2.2.2.2, 00:00:27 ago
      Route metric is 0, traffic share count is 1
      AS Hops 1, BGP network version 478

R3#sh ip bgp 156.1.0.0
BGP routing table entry for 156.1.0.0/16, version 478
Paths: (2 available, best #2)
  Advertised to non peer-group peers:
    1.1.1.1
  4 12
    1.1.1.1 from 1.1.1.1 (1.1.1.1)
      Origin IGP, localpref 100, valid, internal
  12
    142.108.10.2 from 2.2.2.2 (2.2.2.2)
      Origin IGP, metric 0, localpref 100, valid, internal, best
```

Route Oscillation – Troubleshooting

Let’s take a look at the next hop at this point!

```
R3#show ip route 142.108.10.2
Routing entry for 142.108.0.0/16
  Known via "bgp 3", distance 200, metric 0
 Routing Descriptor Blocks:
  * 142.108.10.2, from 2.2.2.2, 00:00:50 ago
      Route metric is 0, traffic share count is 1
      AS Hops 1, BGP network version 476

R3#show ip bgp 142.108.10.2
BGP routing table entry for 142.108.0.0/16, version 476
Paths: (2 available, best #2)
  Advertised to non peer-group peers:
    1.1.1.1
  4 12
    1.1.1.1 from 1.1.1.1 (1.1.1.1)
      Origin IGP, localpref 100, valid, internal
  12
    142.108.10.2 from 2.2.2.2 (2.2.2.2)
      Origin IGP, metric 0, localpref 100, valid, internal, best
```

Route Oscillation – Troubleshooting

Next-hop is recursive !!!

This will be detected next time the scanner runs and the other path will be installed in the RIB instead

```
R3#sh debug
  BGP events debugging is on
  BGP updates debugging is on
  IP routing debugging is on
R3#
BGP: scanning routing tables
BGP: nettable_walker 142.108.0.0/16 calling revise_route
RT: del 142.108.0.0 via 142.108.10.2, bgp metric [200/0]
BGP: revise route installing 142.108.0.0/16 -> 1.1.1.1
RT: add 142.108.0.0/16 via 1.1.1.1, bgp metric [200/0]
RT: del 156.1.0.0 via 142.108.10.2, bgp metric [200/0]
BGP: revise route installing 156.1.0.0/16 -> 1.1.1.1
RT: add 156.1.0.0/16 via 1.1.1.1, bgp metric [200/0]
```

Route Oscillation – Troubleshooting

The route to the next-hop is now valid and at the next bgp scan we will change to the shorter as-path path, and so on …

```
R3#
BGP: scanning routing tables
BGP:  ip nettable_walker 142.108.0.0/16 calling revise_route
RT: del 142.108.0.0 via 1.1.1.1, bgp metric [200/0]
BGP: revise route installing 142.108.0.0/16 -> 142.108.10.2
RT: add 142.108.0.0/16 via 142.108.10.2, bgp metric [200/0]
BGP: nettable_walker 156.1.0.0/16 calling revise_route
RT: del 156.1.0.0 via 1.1.1.1, bgp metric [200/0]
BGP: revise route installing 156.1.0.0/16 -> 142.108.10.2
RT: add 156.1.0.0/16 via 142.108.10.2, bgp metric [200/0]
```

Route Oscillation – Summary

- iBGP preserves the next-hop information from eBGP
- To avoid problems

  use “next-hop-self” for iBGP peering

  -or-

  make sure you advertise the next-hop prefix via the IGP

Inconsistent Route Selection

- Two common problems with route selection
  - Inconsistency
  - Appearance of an Incorrect decision
- RFC 1771 defines the decision algorithm
- Every vendor has tweaked the algorithm
  - http://www.cisco.com/warp/public/459/25.shtml
- Route Selection problems can result from oversights in RFC1771

Inconsistent Route Selection

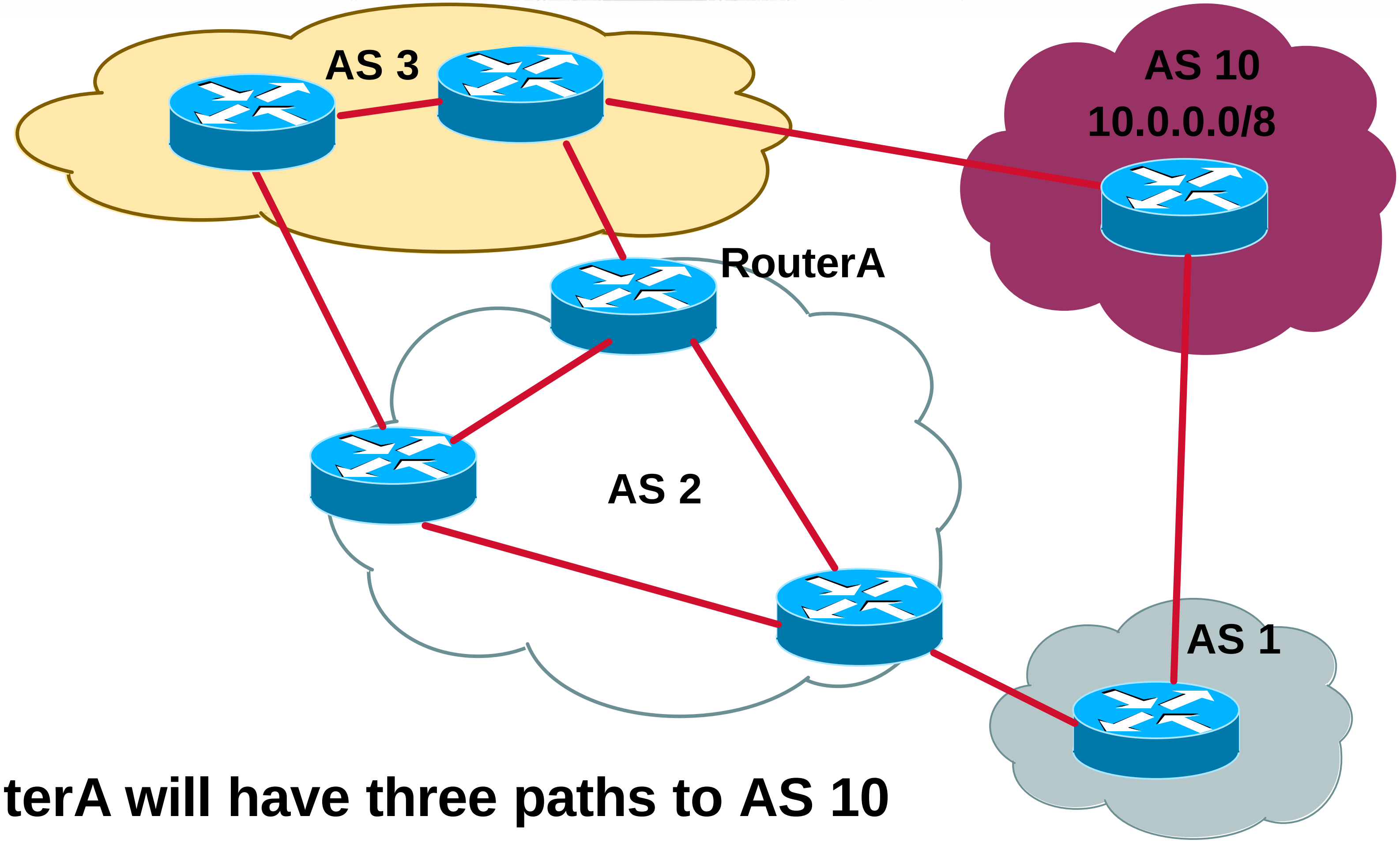
- RFC says that MED is not always compared
- As a result, the ordering of the paths can affect the decision process
- By default, the prefixes are compared in order of arrival (most recent to oldest)

  use bgp deterministic-med to order paths consistently

  the bestpath is recalculated as soon as the command is entered

  enable in all the routers in the AS

Symptom – Diagram



- RouterA will have three paths to AS 10
- MEDs from AS 3 will not be compared with MEDs from AS 1

Inconsistent Route Selection

```
RouterA#sh ip bgp 10.0.0.0
BGP routing table entry for 10.0.0.0/8, version 40
Paths: (3 available, best #3, advertised over IBGP, EBGP)
  3 10
    2.2.2.2 from 2.2.2.2
      Origin IGP, metric 20, localpref 100, valid, internal
  3 10
    3.3.3.3 from 3.3.3.3
      Origin IGP, metric 30, valid, external
  1 10
    1.1.1.1 from 1.1.1.1
      Origin IGP, metric 0, localpref 100, valid, internal, best
```

- **Initial State**

  Path 1 beats Path 2 – Lower MED

  Path 3 beats Path 1 – Lower Router-ID

Inconsistent Route Selection

```
RouterA#sh ip bgp 10.0.0.0
BGP routing table entry for 10.0.0.0/8, version 40
Paths: (3 available, best #3, advertised over IBGP, EBGP)
  1 10
    1.1.1.1 from 1.1.1.1
      Origin IGP, metric 0, localpref 100, valid, internal
  3 10
    2.2.2.2 from 2.2.2.2
      Origin IGP, metric 20, localpref 100, valid, internal
  3 10
    3.3.3.3 from 3.3.3.3
      Origin IGP, metric 30, valid, external, best
```

- **1.1.1.1 bounced so the paths are re-ordered**

  Path 1 beats Path 2 – Lower Router-ID

  Path 3 beats Path 1 – External vs Internal

Deterministic MED – Operation

- The paths are ordered by Neighbour AS
- The bestpath for each Neighbour AS group is selected
- The overall bestpath results from comparing the winners from each group
- The bestpath will be consistent because paths will be placed in a deterministic order

Deterministic MED – Result

```
RouterA#sh ip bgp 10.0.0.0
BGP routing table entry for 10.0.0.0/8, version 40
Paths: (3 available, best #1, advertised over IBGP, EBGP)
  1 10
    1.1.1.1 from 1.1.1.1
      Origin IGP, metric 0, localpref 100, valid, internal, best
  3 10
    2.2.2.2 from 2.2.2.2
      Origin IGP, metric 20, localpref 100, valid, internal
  3 10
    3.3.3.3 from 3.3.3.3
      Origin IGP, metric 30, valid, external
```

Path 1 is best for AS 1

Path 2 beats Path 3 for AS 3 – Lower MED

Path 1 beats Path 2 – Lower Router-ID

Deterministic MED – Summary

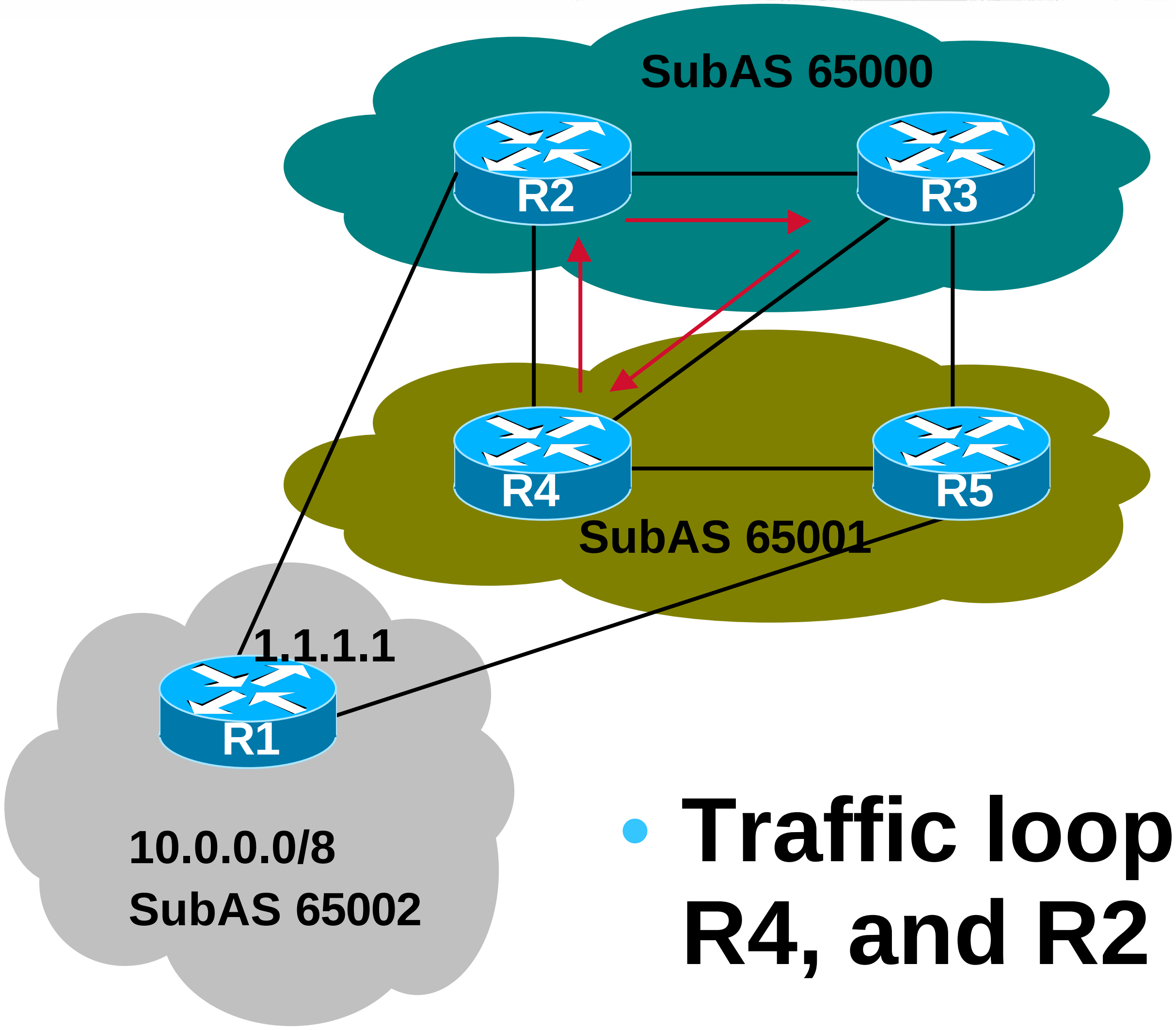
- **If multihoming with multiple ISPs and peering with one ISP at multiple points:**

  use “bgp deterministic-med”

  enable it on all routers in the AS

- **Always use “bgp deterministic-med”**

Routing Loop – Problem



```
traceroute 10.1.1.1

 1 30.100.1.1
 2 20.20.20.4  - R3
 3 30.1.1.26   - R4
 4 30.1.1.17   - R2
 5 20.20.20.4  - R3
 6 30.1.1.26   - R4
 7 30.1.1.17   - R2
 8 20.20.20.4
 9 30.1.1.26
10 30.1.1.17
```

- Traffic loops between R3, R4, and R2

Routing Loop – Diagnosis

- First grab a “show ip route” from the three problem routers
- R3 is forwarding traffic to 1.1.1.1 (R1)

```
R3# show ip route 10.1.1.1
Routing entry for 10.0.0.0/8
  Known via "bgp 65000", distance 200, metric 0
  Routing Descriptor Blocks:
    1.1.1.1, from 5.5.5.5, 01:46:43 ago
      Route metric is 0, traffic share count is 1
      AS Hops 0, BGP network version 0
  * 1.1.1.1, from 4.4.4.4, 01:46:43 ago
      Route metric is 0, traffic share count is 1
      AS Hops 0, BGP network version 0
```

Routing Loop – Diagnosis

- R4 is also forwarding to 1.1.1.1 (R1)

```
R4# show ip route 10.1.1.1
Routing entry for 10.0.0.0/8
  Known via "bgp 65001", distance 200, metric 0
  Routing Descriptor Blocks:
  * 1.1.1.1, from 5.5.5.5, 01:47:02 ago
      Route metric is 0, traffic share count is 1
      AS Hops 0
```

Routing Loop – Diagnosis

- R2 is forwarding to 3.3.3.3? (R3)

```
R2# show ip route 10.1.1.1
Routing entry for 10.0.0.0/8
  Known via "bgp 65000", distance 200, metric 0
Routing Descriptor Blocks:
  * 3.3.3.3, from 3.3.3.3, 01:47:00 ago
      Route metric is 0, traffic share count is 1
      AS Hops 0, BGP network version 3
```

- Very odd that the NEXT_HOP is in the middle of the network

Routing Loop – Diagnosis

- Verify BGP paths on R2

```
R2#show ip bgp 10.0.0.0
BGP routing table entry for 10.0.0.0/8, version 3
Paths: (4 available, best #1)
  Advertised to non peer-group peers:
    1.1.1.1 5.5.5.5 4.4.4.4
  (65001 65002)
    3.3.3.3 (metric 11) from 3.3.3.3 (3.3.3.3)
      Origin IGP, metric 0, localpref 100, valid, confed-
internal, best
 (65002)
    1.1.1.1 (metric 5010) from 1.1.1.1 (1.1.1.1)
      Origin IGP, metric 0, localpref 100, valid, confed-
external
```

- R3 path is better than R1 path because of IGP cost to NEXT_HOP
- R3 is advertising the path to us with a NEXT_HOP of 3.3.3.3 ???

Routing Loop – Diagnosis

- What is R3 advertising?

```
R3# show ip bgp 10.0.0.0
BGP routing table entry for 10.0.0.0/8, version 3
Paths: (2 available, best #1, table Default-IP-Routing-Table)
  Advertised to non peer-group peers:
  5.5.5.5 2.2.2.2
  (65001 65002)
    1.1.1.1 (metric 5031) from 4.4.4.4 (4.4.4.4)
      Origin IGP, metric 0, localpref 100, valid, confed-
external, best, multipath
  (65001 65002)
    1.1.1.1 (metric 5031) from 5.5.5.5 (5.5.5.5)
      Origin IGP, metric 0, localpref 100, valid, confed-
external, multipath
```

- Hmmm, R3 is using multipath to load-balance

```
R3#show run | include maximum
 maximum-paths 6
```

Routing Loop – Solution

- “maximum-paths” tells the router to reset the NEXT_HOP to himself

  R3 sets NEXT_HOP to 3.3.3.3

- Forces traffic to come to him so he can load-balance

- Is typically used for multiple eBGP sessions to an AS

  Be careful when using in Confederations!!

- Need to make R2 prefer the path from R1 to prevent the routing loop

  Make IGP metric to 1.1.1.1 better than IGP metric to 4.4.4.4

Troubleshooting Tips

- High CPU in “Router BGP” is normally a sign of a convergence problem
- Find a prefix that changes every minute

```
show ip route | include , 00:00
```

- Troubleshoot/debug that one prefix

Troubleshooting Tips

- BGP routing loop?
  - First, check for IGP routing loops to BGP NEXT_HOPs
- BGP loops are normally caused by
  - Not following physical topology in RR environment
  - Multipath within confederations
  - Lack of a full iBGP mesh
- Get the following from each router in the loop path
  - show ip route x.x.x.x
  - show ip bgp x.x.x.x
  - show ip route NEXT_HOP

Troubleshooting Tips

- “show ip bgp neighbor x.x.x.x advertised-routes”

  Lets you see a list of NLRI that you sent a peer

  Note: The attribute values shown are taken from the BGP table. Attribute modifications by outbound route-maps will not be shown.

- “show ip bgp neighbor x.x.x.x routes”

  Displays routes x.x.x.x sent to us that made it through our inbound filters

- “show ip bgp neighbor x.x.x.x received-routes”

  Can only use if “soft-reconfig inbound” is configured

  Displays all routes received from a peer, even those that were denied

Troubleshooting Tips

- “clear ip bgp x.x.x.x in”

  Ask x.x.x.x to resend his UPDATEs to us

- “clear ip bgp x.x.x.x out”

  Tells BGP to resend UPDATEs to x.x.x.x

- “debug ip bgp update”

  Always use an ACL to limit output

  Great for troubleshooting “Automatic Denies”

- “debug ip bgp x.x.x.x update”

  Allows you to debug updates to/from a specific peer

  Handy if multiple peers are sending you the same prefix

Summary/Tips

- Isolate the problem!!
- Use ACLs when enabling debug commands
- Enable bgp log-neighbor-changes
- IP reachability must exist for sessions to be established

  learned from IGP

  make sure the source and destination addresses match the configuration

BGP for Internet Service Providers

- BGP Basics (quick recap)
- Scaling BGP
- Deploying BGP in an ISP network
- Trouble & Troubleshooting
- Multihoming Examples
- Using Communities

Multihoming

Multihoming Definition

- More than one link external to the local network

  two or more links to the same ISP

  two or more links to different ISPs

- Usually two external facing routers

  one router gives link and provider redundancy only

AS Numbers

- An Autonomous System Number is required by BGP
- Obtained from upstream ISP or Regional Registry
- Necessary when you have links to more than one ISP or exchange point

Configuring Policy

- Three BASIC Principles

  prefix-lists to filter prefixes

  filter-lists to filter ASNs

  route-maps to apply policy

- Avoids confusion!

Originating Prefixes

- Basic Assumptions

  MUST announce assigned address block to Internet

  MAY also announce subprefixes – reachability is not guaranteed

  RIR minimum allocation is /20

  - several ISPs filter RIR blocks on this boundary
  - called “Net Police” by some

Part of the “Net Police” prefix list

```
!! APNIC
ip prefix-list FILTER permit 61.0.0.0/8 ge 9 le 20
ip prefix-list FILTER permit 202.0.0.0/7 ge 9 le 20
ip prefix-list FILTER permit 210.0.0.0/7 ge 9 le 20
ip prefix-list FILTER permit 218.0.0.0/8 ge 9 le 20
!! ARIN
ip prefix-list FILTER permit 63.0.0.0/8 ge 9 le 20
ip prefix-list FILTER permit 64.0.0.0/7 ge 9 le 20
ip prefix-list FILTER permit 66.0.0.0/8 ge 9 le 20
ip prefix-list FILTER permit 199.0.0.0/8 ge 9 le 20
ip prefix-list FILTER permit 200.0.0.0/8 ge 9 le 20
ip prefix-list FILTER permit 204.0.0.0/6 ge 9 le 20
ip prefix-list FILTER permit 208.0.0.0/7 ge 9 le 20
ip prefix-list FILTER permit 216.0.0.0/8 ge 9 le 20
!! RIPE NCC
ip prefix-list FILTER permit 62.0.0.0/8 ge 9 le 20
ip prefix-list FILTER permit 80.0.0.0/7 ge 9 le 20
ip prefix-list FILTER permit 193.0.0.0/8 ge 9 le 20
ip prefix-list FILTER permit 194.0.0.0/7 ge 9 le 20
ip prefix-list FILTER permit 212.0.0.0/7 ge 9 le 20
```

“Net Police” prefix list issues

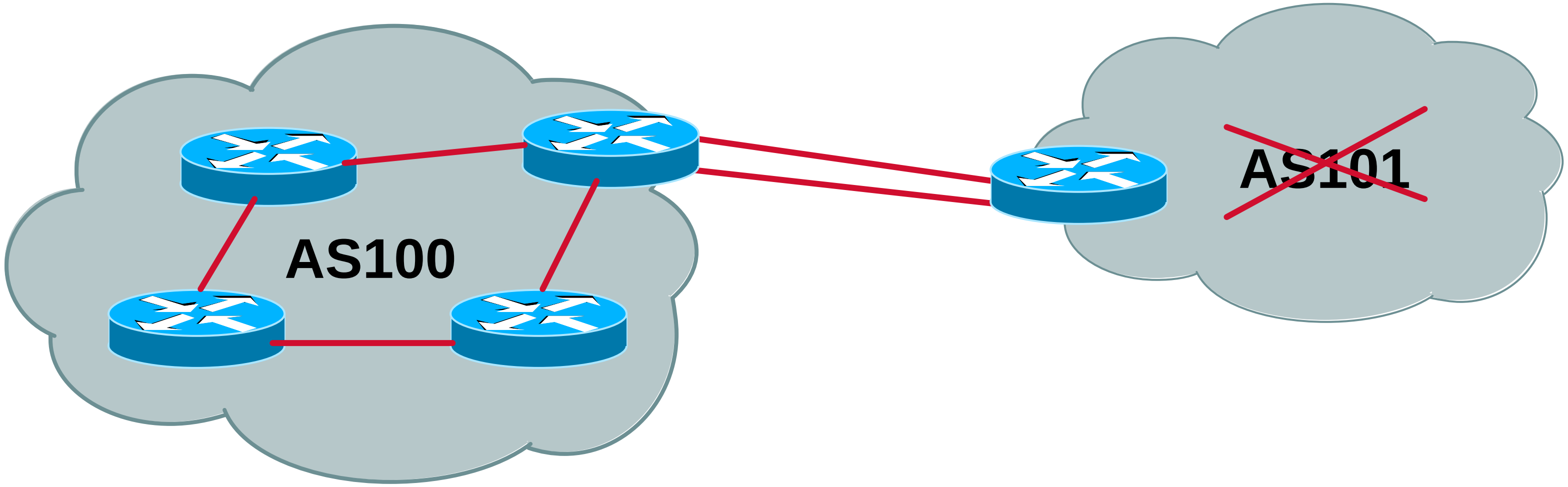
- meant to “punish” ISPs who won’t and don’t aggregate
- impacts legitimate multihoming
- impacts regions where domestic backbone is unavailable or costs $$$ compared with international bandwidth
- hard to maintain – requires updating when RIRs start allocating from new address blocks
- don’t do it unless consequences understood and you are prepared to keep it current

Multihoming Options

Multihoming Scenarios

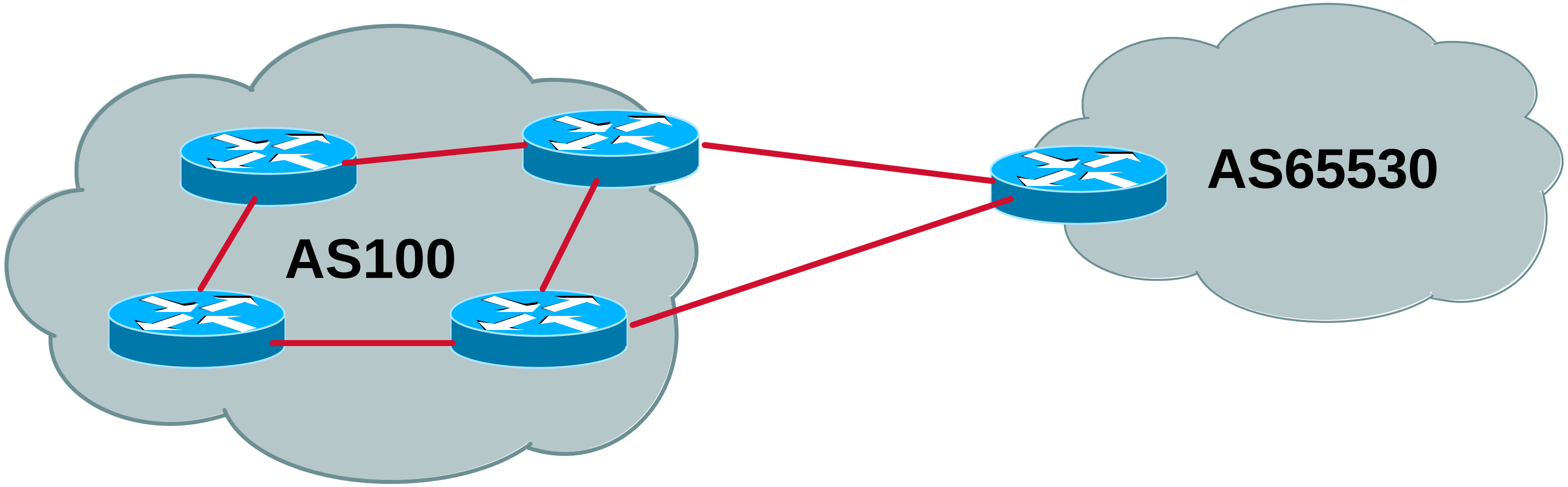
- **Stub network**
- **Multi-homed stub network**
- **Multi-homed network**
- **Configuration Options**

Stub Network



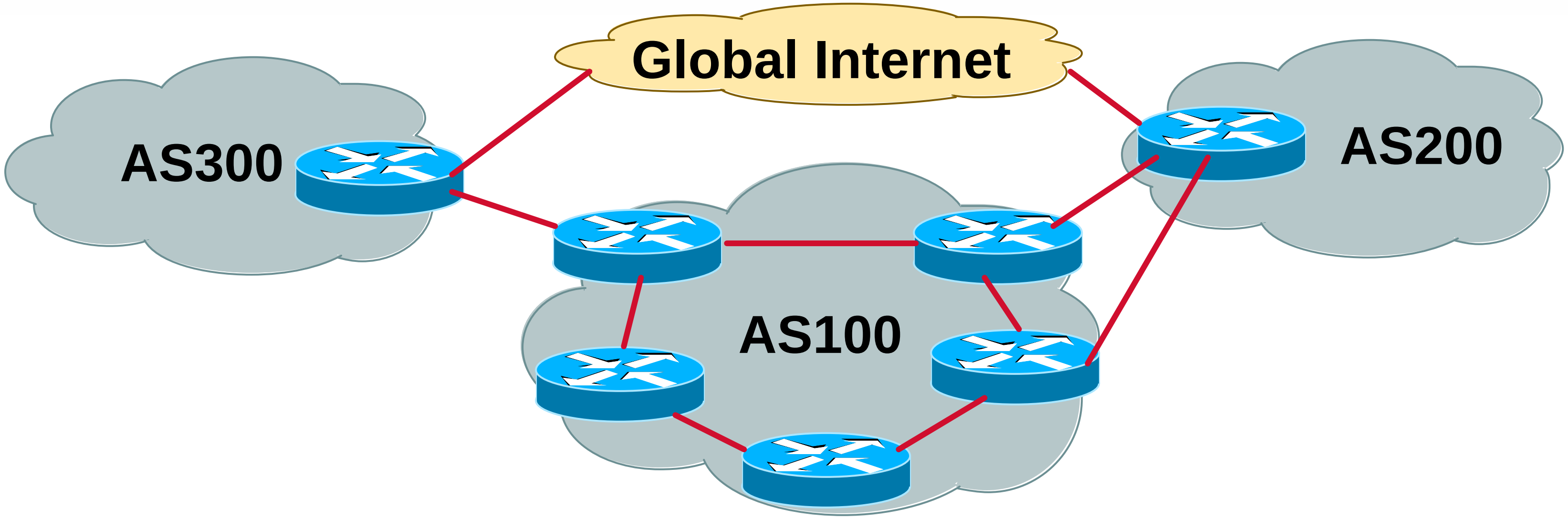
- No need for BGP
- Point static default to upstream ISP
- Upstream ISP advertises stub network
- Policy confined within upstream ISP's policy

Multi-homed Stub Network



- Use BGP (not IGP or static) to loadshare
- Use private AS (ASN > 64511)
- Upstream ISP advertises stub network
- Policy confined within upstream ISP's policy

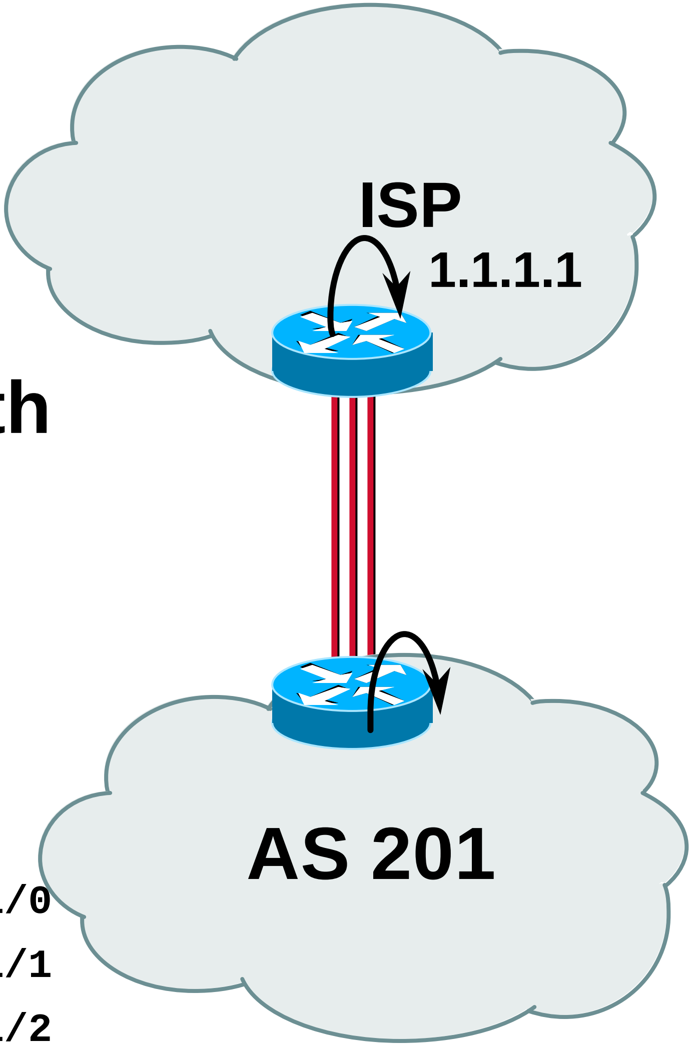
Multi-Homed Network



- **Many situations possible**
  - multiple sessions to same ISP
  - secondary for backup only
  - load-share between primary and secondary
  - selectively use different ISPs

Multiple Sessions to an ISP – Example One

- **eBGP multihop**
- **eBGP to loopback addresses**
- **eBGP prefixes learned with loopback address as next hop**

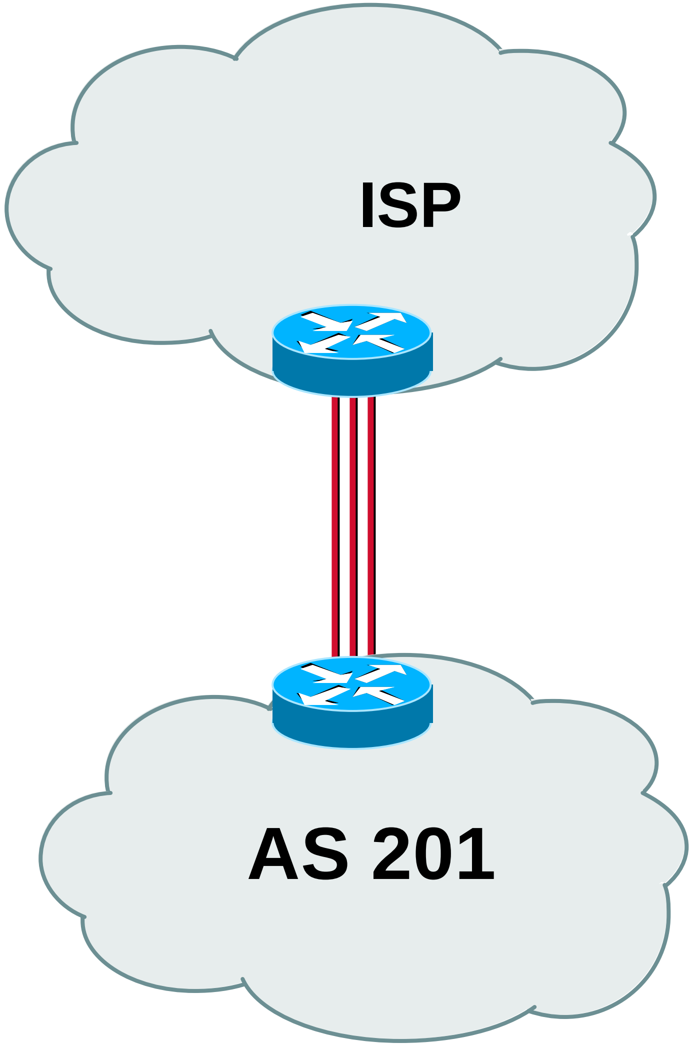


```
router bgp 201
 neighbor 1.1.1.1 remote-as 200
 neighbor 1.1.1.1 ebgp-multihop 5
ip route 1.1.1.1 255.255.255.255 serial 1/0
ip route 1.1.1.1 255.255.255.255 serial 1/1
ip route 1.1.1.1 255.255.255.255 serial 1/2
```

Multiple Sessions to an ISP – Example Two

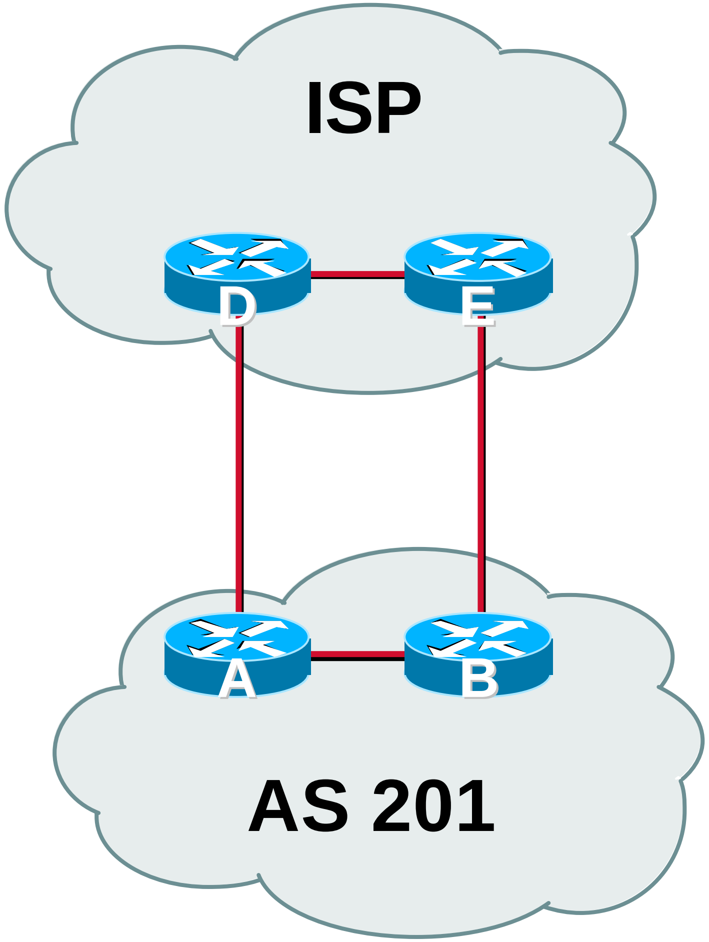
- BGP multi-path
- Three BGP sessions required
- limit of 6 parallel paths

```
router bgp 201
 neighbor 1.1.2.1 remote-as 200
 neighbor 1.1.2.5 remote-as 200
 neighbor 1.1.2.9 remote-as 200
 maximum-paths 3
```



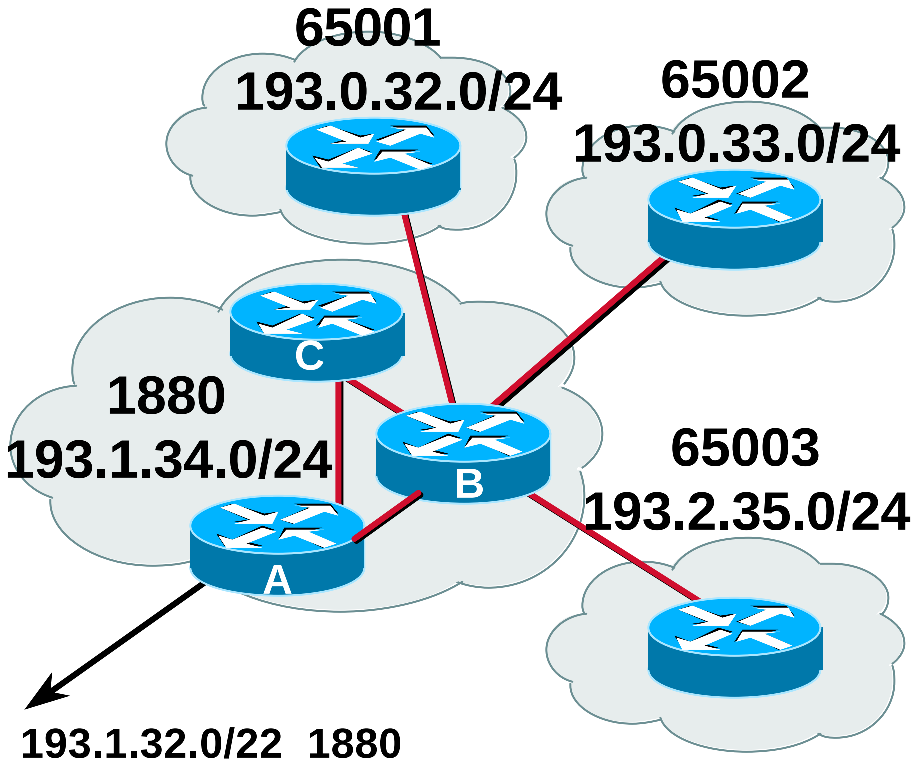
Multiple Sessions to an ISP

- Simplest scheme is to use defaults
- Learn/advertise prefixes for better control
- Planning and some work required to achieve loadsharing
- No magic solution



Private-AS – Application

- Applications
  - ISP with single-homed customers (RFC2270)
  - corporate network with several regions and connections to the Internet only in the core



Private-AS Removal

- neighbor x.x.x.x remove-private-AS
- Rules:

  available for eBGP neighbors only

  if the update has AS_PATH made up of private-AS numbers, the private-AS will be dropped

  if the AS_PATH includes private and public AS numbers, private AS number will not be removed…it is a configuration error!

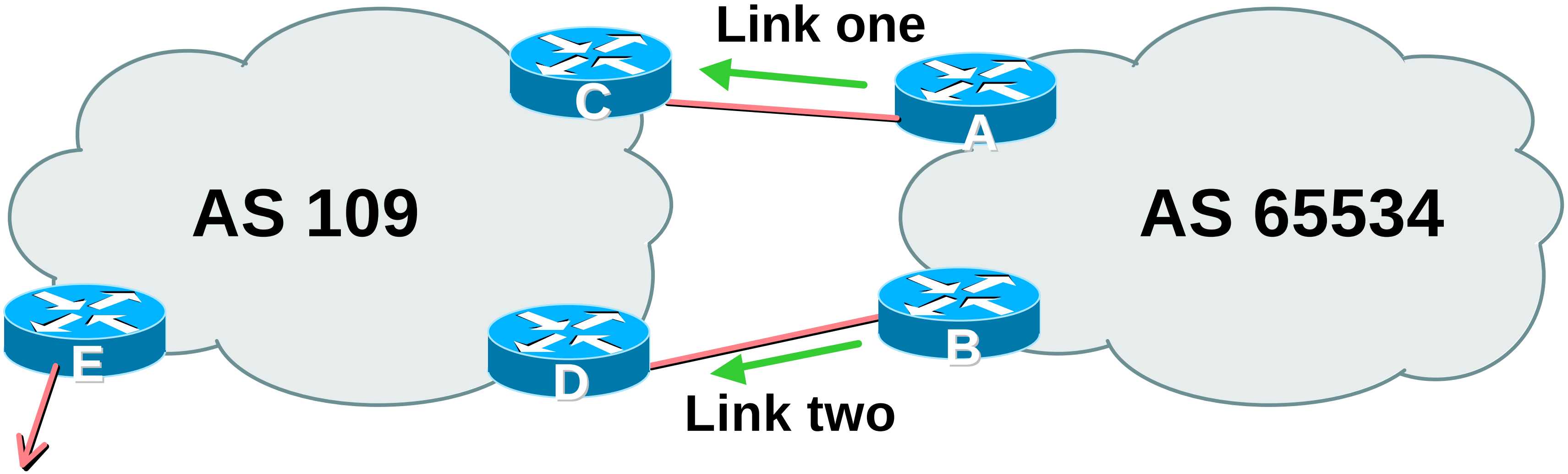
  if AS_PATH contains the AS number of the eBGP neighbor, the private-AS numbers will not be removed

  if used with confederations, it will work as long as the private AS numbers are after the confederation portion of the AS_PATH

Two links to the same ISP

With Redundancy and Loadsharing

Two links to the same ISP (with redundancy)



- **AS109 removes private AS and any customer subprefixes from Internet announcement**

Loadsharing to the same ISP

- Announce /19 aggregate on each link
- Split /19 and announce as two /20s, one on each link

  basic inbound loadsharing

  assumes equal circuit capacity and even spread of traffic across address block
- Vary the split until “perfect” loadsharing achieved
- Accept the default from upstream

  basic outbound loadsharing by nearest exit

  okay in first approx as most ISP and end-site traffic is inbound

Two links to the same ISP

- Router A Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.0.0 mask 255.255.240.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 prefix-list routerC out
 neighbor 222.222.10.2 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerC permit 221.10.0.0/20
ip prefix-list routerC permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.240.0 null0
ip route 221.10.0.0 255.255.224.0 null0
```

Router B configuration is similar but with the other /20

Two links to the same ISP

- Router C Configuration

```
router bgp 109
 neighbor 222.222.10.1 remote-as 65534
 neighbor 222.222.10.1 default-originate
 neighbor 222.222.10.1 prefix-list Customer in
 neighbor 222.222.10.1 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19 le 20
ip prefix-list default permit 0.0.0.0/0
```

- Router C only allows in /19 and /20 prefixes from customer block
- Router D configuration is identical

Loadsharing to the same ISP

- Loadsharing configuration is only on customer router
- Upstream ISP has to

  remove customer subprefixes from external announcements

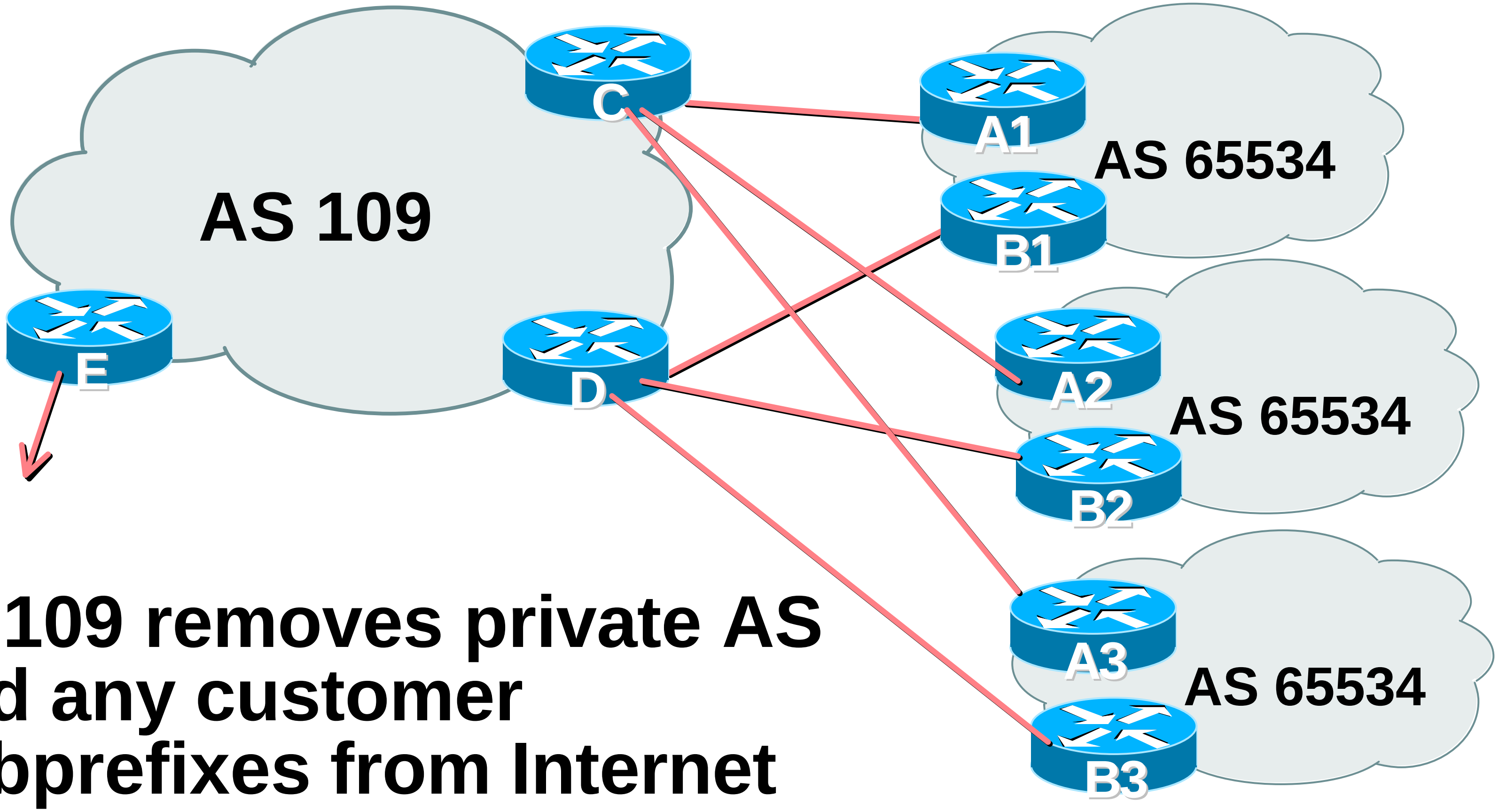
  remove private AS from external announcements
- Could also use BGP communities

Two links to the same ISP

Multiple Dualhomed Customers

(RFC2270)

Multiple Dualhomed Customers (RFC2270)



- **AS109 removes private AS and any customer subprefixes from Internet announcement**

Multiple Dualhomed Customers

- Customer announcements as per previous example
- Use the *same* private AS for each customer
  - documented in RFC2270
  - address space is not overlapping
  - each customer hears default only
- Router A*n* and B*n* configuration same as Router A and B previously

Two links to the same ISP

- ## Router A1 Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.0.0 mask 255.255.240.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 prefix-list routerC out
 neighbor 222.222.10.2 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerC permit 221.10.0.0/20
ip prefix-list routerC permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.240.0 null0
ip route 221.10.0.0 255.255.224.0 null0
```

Router B1 configuration is similar but for the other /20

Multiple Dualhomed Customers

- Router C Configuration

```
router bgp 109
 neighbor bgp-customers peer-group
 neighbor bgp-customers remote-as 65534
 neighbor bgp-customers default-originate
 neighbor bgp-customers prefix-list default out
 neighbor 222.222.10.1 peer-group bgp-customers
 neighbor 222.222.10.1 description Customer One
 neighbor 222.222.10.1 prefix-list Customer1 in
 neighbor 222.222.10.9 peer-group bgp-customers
 neighbor 222.222.10.9 description Customer Two
 neighbor 222.222.10.9 prefix-list Customer2 in
```

Multiple Dualhomed Customers

```
 neighbor 222.222.10.17 peer-group bgp-customers
 neighbor 222.222.10.17 description Customer Three
 neighbor 222.222.10.17 prefix-list Customer3 in
!
ip prefix-list Customer1 permit 221.10.0.0/19 le 20
ip prefix-list Customer2 permit 221.16.64.0/19 le 20
ip prefix-list Customer3 permit 221.14.192.0/19 le 20
ip prefix-list default permit 0.0.0.0/0
```

- **Router C only allows in /19 and /20 prefixes from customer block**
- **Router D configuration is almost identical**

Multiple Dualhomed Customers

- Router E Configuration

  assumes customer address space is not part of upstream’s address block

```
router bgp 109
 neighbor 222.222.10.17 remote-as 110
 neighbor 222.222.10.17 remove-private-AS
 neighbor 222.222.10.17 prefix-list Customers out
!
ip prefix-list Customers permit 221.10.0.0/19
ip prefix-list Customers permit 221.16.64.0/19
ip prefix-list Customers permit 221.14.192.0/19
```

- Private AS still visible inside AS109

Multiple Dualhomed Customers

- If customers’ prefixes come from ISP’s address block

  do NOT announce them to the Internet

  announce ISP aggregate only

- Router E configuration:

```
router bgp 109
 neighbor 222.222.10.17 remote-as 110
 neighbor 222.222.10.17 prefix-list my-aggregate out
!
ip prefix-list my-aggregate permit 221.8.0.0/13
```

Two links to different ISPs

With Redundancy

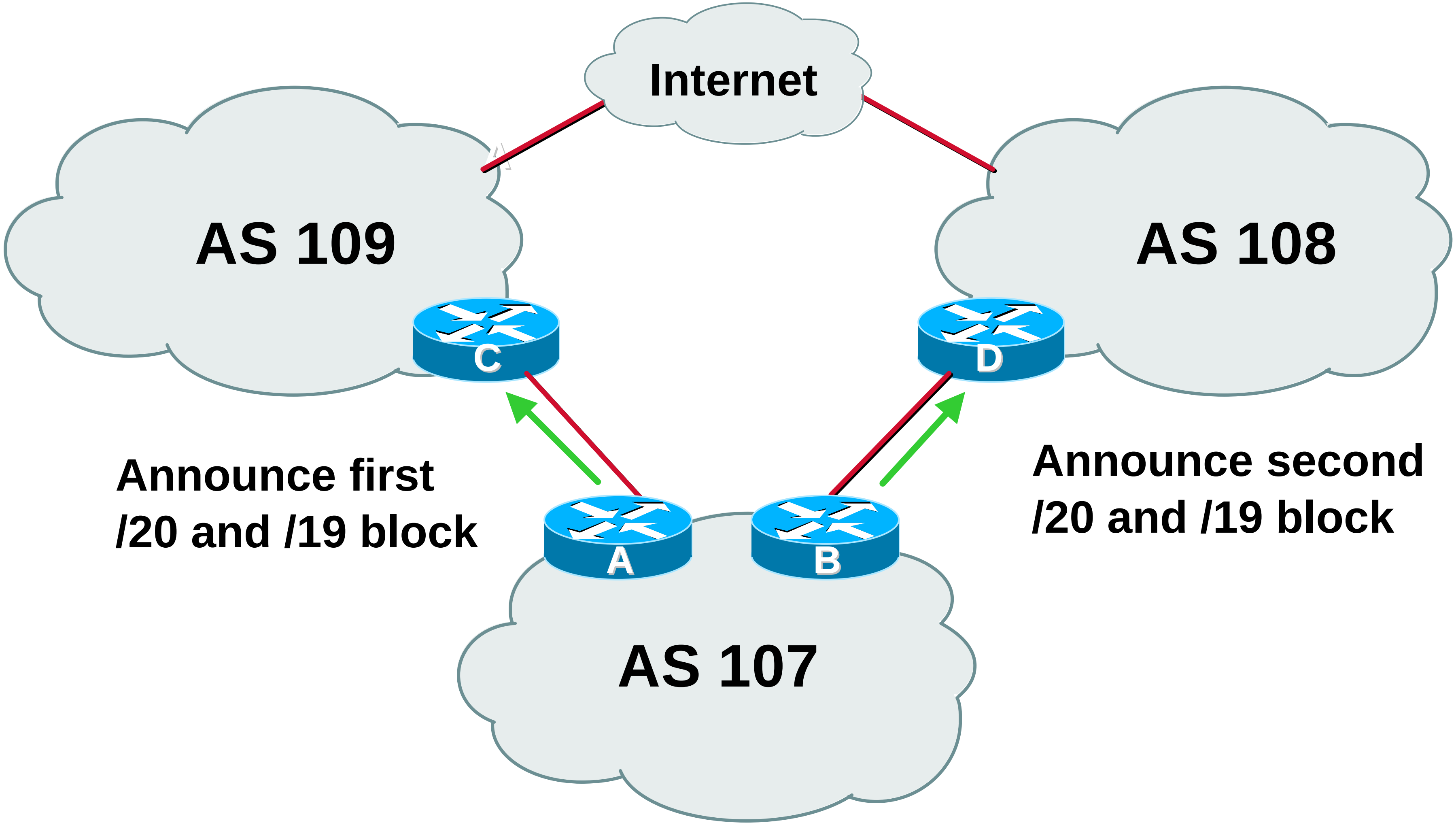
Two links to different ISPs (with redundancy)

- Announce /19 aggregate on each link
- Split /19 and announce as two /20s, one on each link

  basic inbound loadsharing

- When one link fails, the announcement of the /19 aggregate via the other ISP ensures continued connectivity

Two links to different ISPs (with redundancy)



Announce first /20 and /19 block

Announce second /20 and /19 block

Two links to different ISPs (with redundancy)

- Router A Configuration

```
router bgp 107
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.0.0 mask 255.255.240.0
 neighbor 222.222.10.1 remote-as 109
 neighbor 222.222.10.1 prefix-list firstblock out
 neighbor 222.222.10.1 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
!
ip prefix-list firstblock permit 221.10.0.0/20
ip prefix-list firstblock permit 221.10.0.0/19
```

Two links to different ISPs (with redundancy)

- Router B Configuration

```
router bgp 107
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.16.0 mask 255.255.240.0
 neighbor 220.1.5.1 remote-as 108
 neighbor 220.1.5.1 prefix-list secondblock out
 neighbor 220.1.5.1 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
!
ip prefix-list secondblock permit 221.10.16.0/20
ip prefix-list secondblock permit 221.10.0.0/19
```

Two links to different ISPs

More Controlled Loadsharing

Loadsharing with different ISPs

- Announce /19 aggregate on each link

  On first link, announce /19 as normal

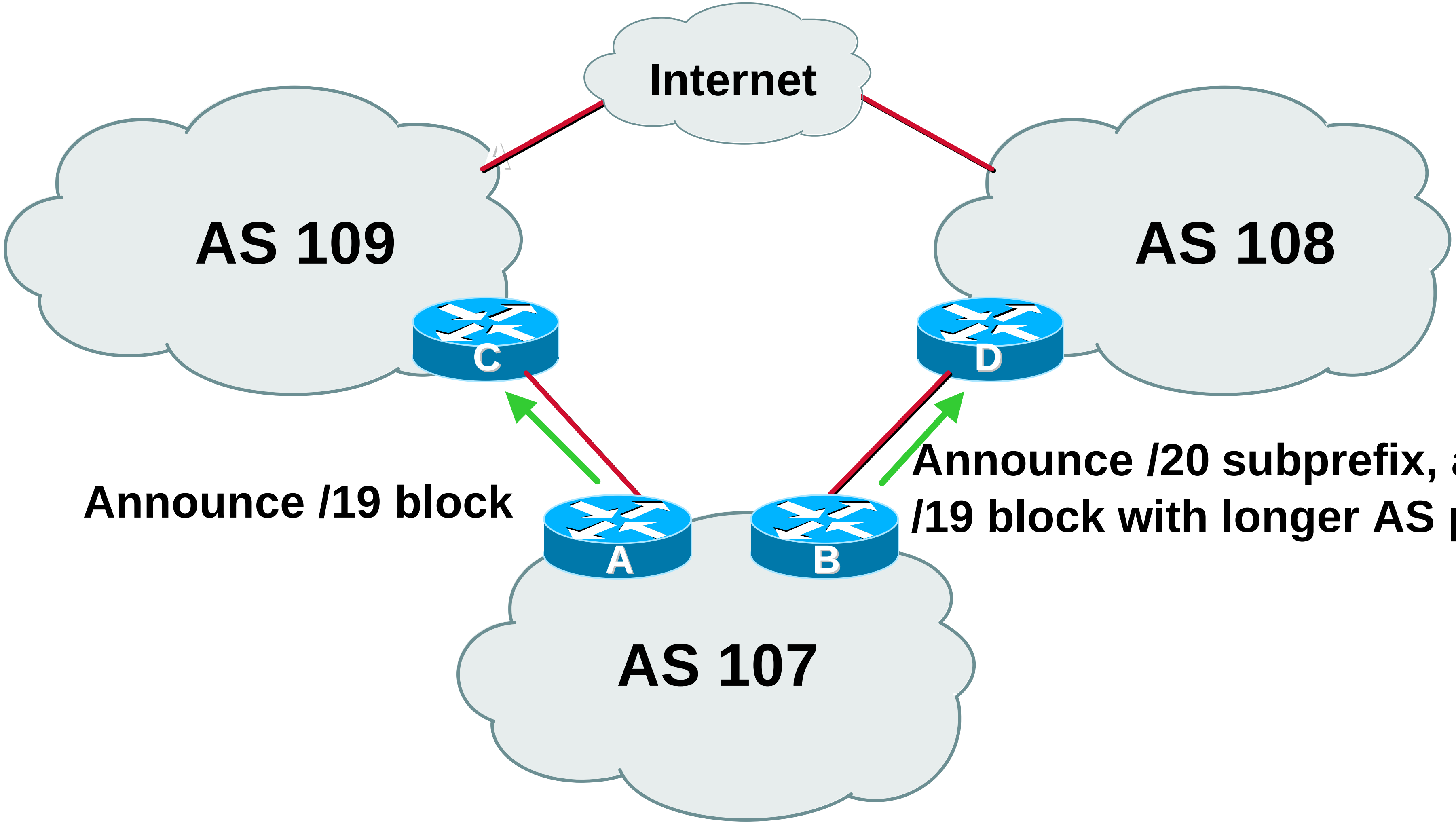
  On second link, announce /19 with longer AS PATH, and announce one /20 subprefix

    controls loadsharing between upstreams and the Internet

- Vary the subprefix size and AS PATH length until “perfect” loadsharing achieved

- Still require redundancy!

Loadsharing with different ISPs



Announce /19 block

Announce /20 subprefix, and /19 block with longer AS path

Loadsharing with different ISPs

- Router A Configuration

```
router bgp 107
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.1 remote-as 109
 neighbor 222.222.10.1 prefix-list default in
 neighbor 222.222.10.1 prefix-list aggregate out
!
ip prefix-list aggregate permit 221.10.0.0/19
```

Loadsharing with different ISPs

- Router B Configuration

```
router bgp 107
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.16.0 mask 255.255.240.0
 neighbor 220.1.5.1 remote-as 108
 neighbor 220.1.5.1 prefix-list default in
 neighbor 220.1.5.1 prefix-list subblocks out
 neighbor 220.1.5.1 route-map routerD out
!
..next slide..
```

Loadsharing with different ISPs

```
route-map routerD permit 10
 match ip address prefix-list aggregate
 set as-path prepend 107 107
route-map routerD permit 20
!
ip prefix-list subblocks permit 221.10.0.0/19 le 20
ip prefix-list aggregate permit 221.10.0.0/19
```

Service Provider Multihoming

Service Provider Multihoming

- Previous examples dealt with loadsharing inbound traffic

  What about outbound?

- ISPs strive to balance traffic flows in both directions

  Balance link utilisation

  Try and keep most traffic flows symmetric

Service Provider Multihoming

- Balancing outbound traffic requires inbound routing information

  Common solution is “full routing table”

  Rarely necessary – the “routing mallet” to try solve loadsharing problems

  Keep It Simple (KISS) is often easier (and $$$ cheaper) than carrying n-copies of the full routing table

Service Provider Multihoming

- Examples

  One upstream, one local peer

  One upstream, local exchange point

  Two upstreams, one local peer

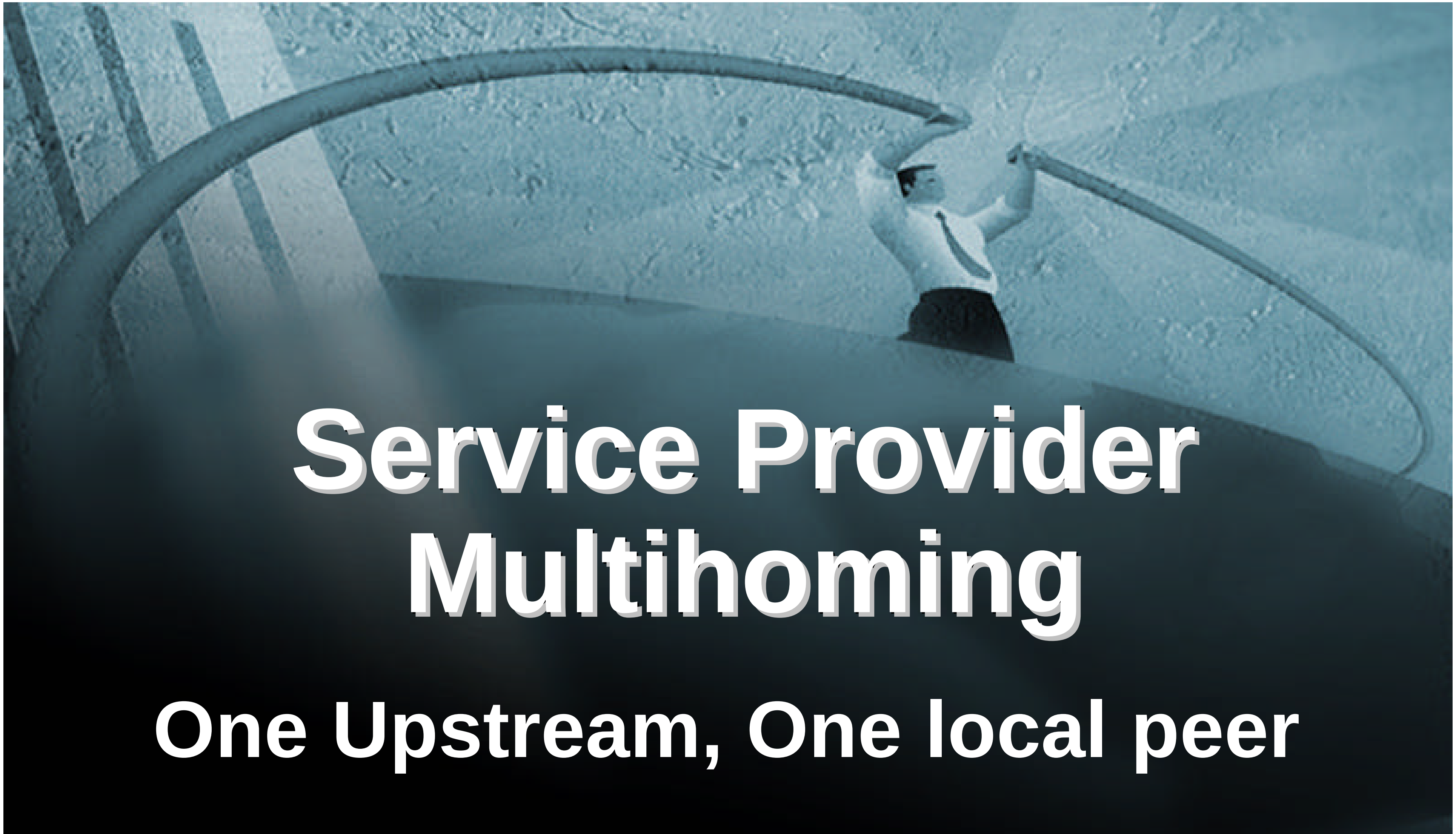
  Two upstreams, one local and one regional peer

  US and regional upstreams, with local peers

  Disconnected Backbone

  IDC Multihoming

- All examples require BGP and a public ASN



Service Provider Multihoming

One Upstream, One local peer

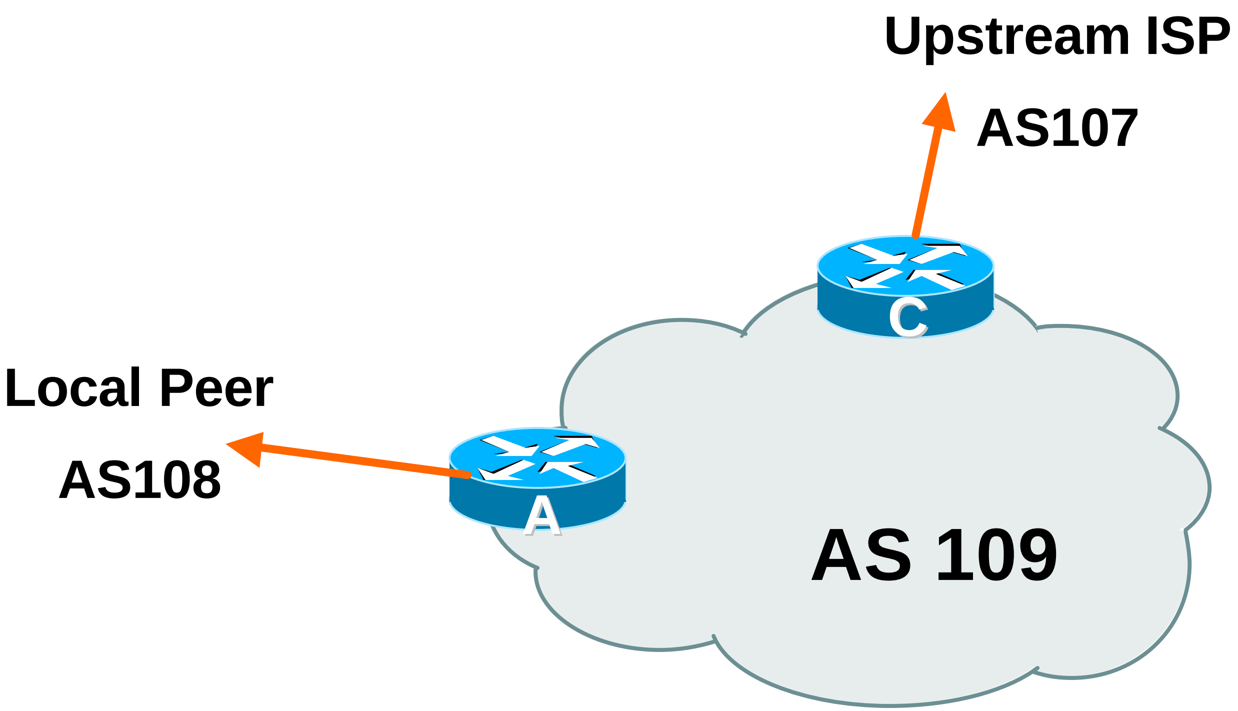
One Upstream, One Local Peer

- Announce /19 aggregate on each link
- Accept default route only from upstream

  Either 0.0.0.0/0 or a network which can be used as default

- Accept all routes from local peer

One Upstream, One Local Peer



One Upstream, One Local Peer

- Router A Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.2 remote-as 108
 neighbor 222.222.10.2 prefix-list my-block out
 neighbor 222.222.10.2 prefix-list AS108-peer in
!
ip prefix-list AS108-peer permit 222.5.16.0/19
ip prefix-list AS108-peer permit 221.240.0.0/20
ip prefix-list my-block permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.224.0 null0
```

One Upstream, One Local Peer

- **Router A – Alternative Configuration**

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.2 remote-as 108
 neighbor 222.222.10.2 prefix-list my-block out
 neighbor 222.222.10.2 filter-list 10 in
!
ip as-path access-list 10 permit ^(108_)+$
!
ip prefix-list my-block permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.224.0 null0
```

One Upstream, One Local Peer

- Router C Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.1 remote-as 107
 neighbor 222.222.10.1 prefix-list default in
 neighbor 222.222.10.1 prefix-list my-block out
!
ip prefix-list my-block permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 221.10.0.0 255.255.224.0 null0
```

One Upstream, One Local Peer

- Two configurations possible for Router A

  Filter-lists assume peer knows what they are doing

  Prefix-list higher maintenance, but safer

- Local traffic goes to and from local peer, everything else goes to upstream

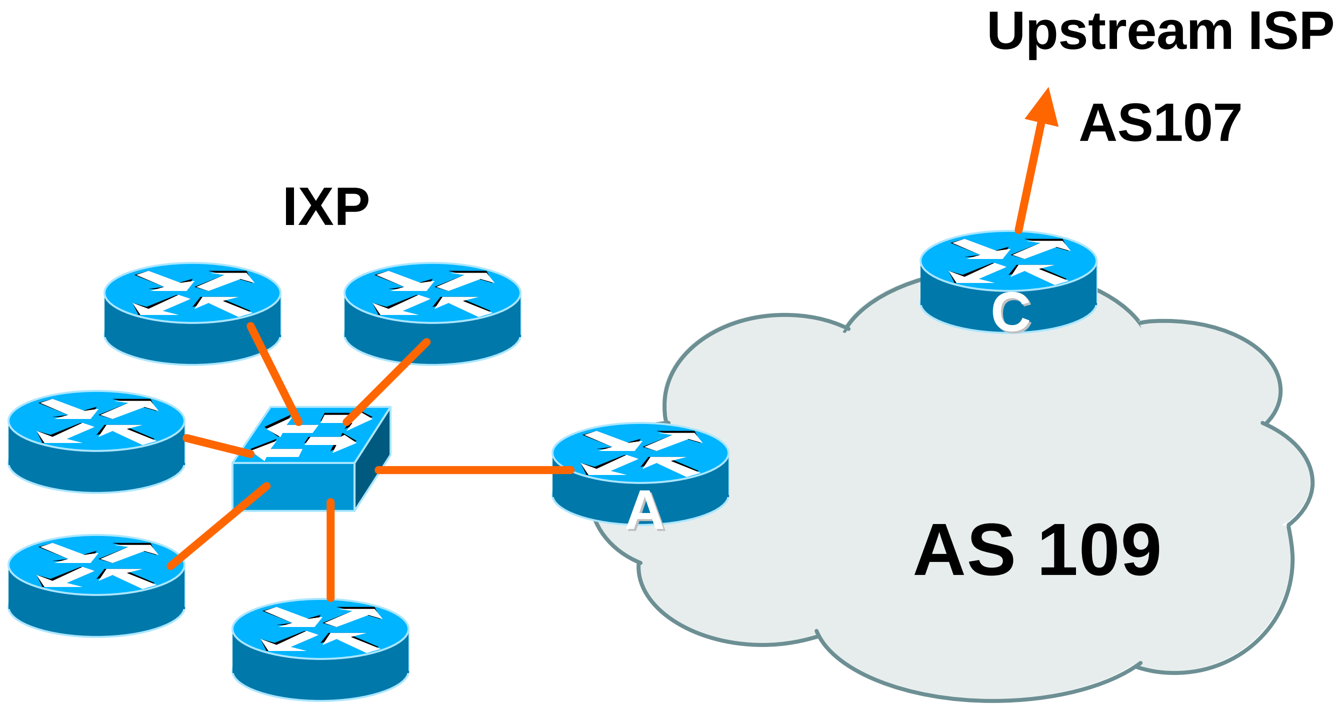
Service Provider Multihoming

One Upstream, Local Exchange Point

One Upstream, Local Exchange Point

- Announce /19 aggregate to every neighbouring AS
- Accept default route only from upstream
  - Either 0.0.0.0/0 or a network which can be used as default
- Accept all routes from IXP peers

One Upstream, Local Exchange Point



One Upstream, Local Exchange Point

- Router A Configuration

```
interface fastethernet 0/0
 description Exchange Point LAN
 ip address 220.5.10.1 mask 255.255.255.224
 ip verify unicast reverse-path
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
!
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor ixp-peers peer-group
 neighbor ixp-peers soft-reconfiguration in
 neighbor ixp-peers prefix-list my-block out
..next slide
```

One Upstream, Local Exchange Point

```
neighbor 220.5.10.2 remote-as 100
neighbor 222.5.10.2 peer-group ixp-peers
neighbor 222.5.10.2 prefix-list peer100 in
neighbor 220.5.10.3 remote-as 101
neighbor 222.5.10.3 peer-group ixp-peers
neighbor 222.5.10.3 prefix-list peer101 in
neighbor 220.5.10.4 remote-as 102
neighbor 222.5.10.4 peer-group ixp-peers
neighbor 222.5.10.4 prefix-list peer102 in
neighbor 220.5.10.5 remote-as 103
neighbor 222.5.10.5 peer-group ixp-peers
neighbor 222.5.10.5 prefix-list peer103 in
```

..next slide

One Upstream, Local Exchange Point

```
ip route 221.10.0.0 255.255.224.0 null0
!
ip route 221.10.0.0 255.255.224.0 null0
!
ip prefix-list my-block permit 221.10.0.0/19
ip prefix-list peer100 permit 222.0.0.0/19
ip prefix-list peer101 permit 222.30.0.0/19
ip prefix-list peer102 permit 222.12.0.0/19
ip prefix-list peer103 permit 222.18.128.0/19
!
```

One Upstream, Local Exchange Point

- Router C Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.1 remote-as 107
 neighbor 222.222.10.1 prefix-list default in
 neighbor 222.222.10.1 prefix-list my-block out
!
ip prefix-list my-block permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 221.10.0.0 255.255.224.0 null0
```

One Upstream, Local Exchange Point

- Note Router A configuration

  Prefix-list higher maintenance, but safer

  uRPF on the FastEthernet interface

- IXP traffic goes to and from local IXP, everything else goes to upstream

Service Provider Multihoming

Two Upstreams, One local peer

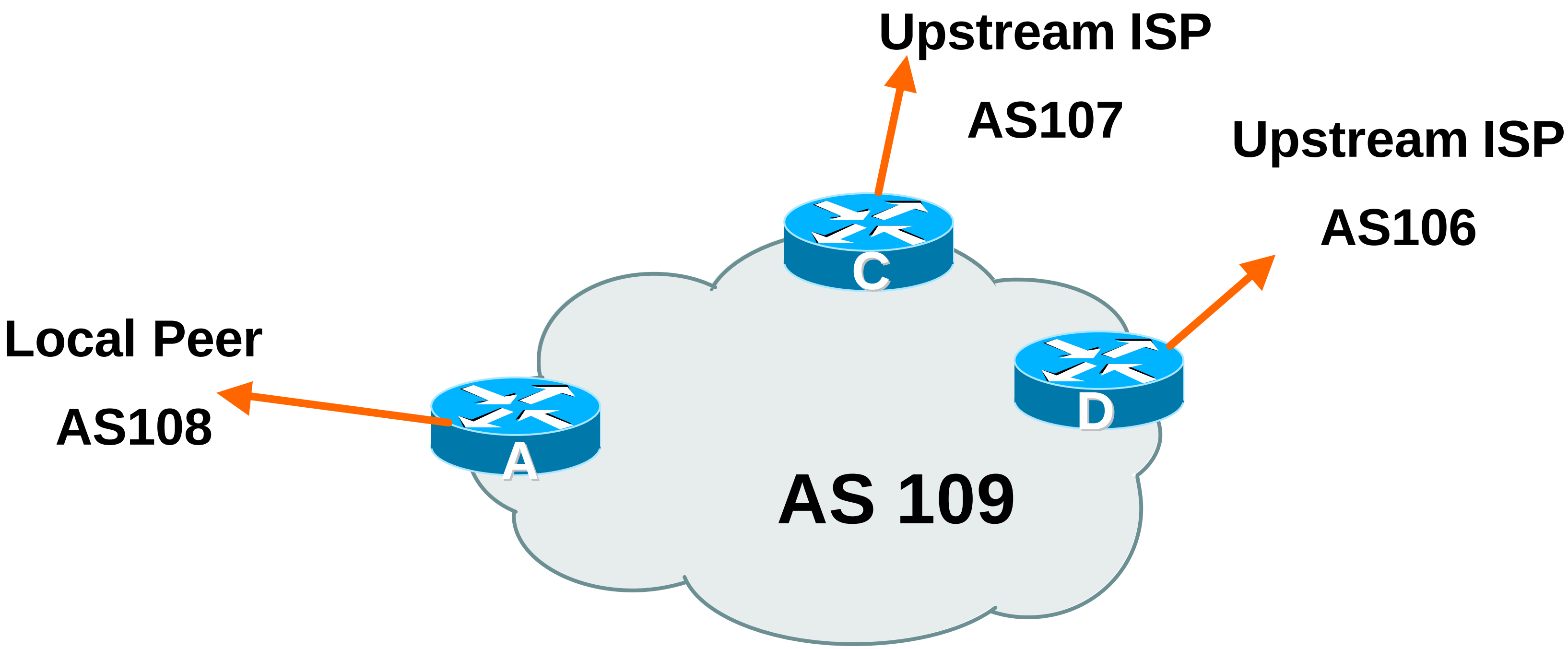
Two Upstreams, One Local Peer

- Announce /19 aggregate on each link
- Accept default route only from upstreams

  Either 0.0.0.0/0 or a network which can be used as default

- Accept all routes from local peer

Two Upstreams, One Local Peer



Upstream ISP

AS107

Upstream ISP

AS106

Local Peer

AS108

Two Upstreams, One Local Peer

- Router A

  Same routing configuration as in example with one upstream and one local peer

  Same hardware configuration

Two Upstreams, One Local Peer

- Router C Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.1 remote-as 107
 neighbor 222.222.10.1 prefix-list default in
 neighbor 222.222.10.1 prefix-list my-block out
!
ip prefix-list my-block permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 221.10.0.0 255.255.224.0 null0
```

Two Upstreams, One Local Peer

- Router D Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.5 remote-as 106
 neighbor 222.222.10.5 prefix-list default in
 neighbor 222.222.10.5 prefix-list my-block out
!
ip prefix-list my-block permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 221.10.0.0 255.255.224.0 null0
```

Two Upstreams, One Local Peer

- This is the simple configuration for Router C and D
- Traffic out to the two upstreams will take nearest exit

  Inexpensive routers required

  This is not useful in practice especially for international links

  Loadsharing needs to be better

Two Upstreams, One Local Peer

- Better configuration options:
  - Accept full routing from both upstreams
    - Expensive & unnecessary!
  - Accept default from one upstream and some routes from the other upstream
    - The way to go!

Two Upstreams, One Local Peer – Full Routes

- Router C Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.1 remote-as 107
 neighbor 222.222.10.1 prefix-list rfc1918-deny in
 neighbor 222.222.10.1 prefix-list my-block out
 neighbor 222.222.10.1 route-map AS107-loadshare in
!
ip prefix-list my-block permit 221.10.0.0/19
! See earlier presentation for RFC1918 list
..next slide
```

Two Upstreams, One Local Peer – Full Routes

```
ip route 221.10.0.0 255.255.224.0 null0
!
ip as-path access-list 10 permit ^(107_)+$
ip as-path access-list 10 permit ^(107_)+_[0-9]+$
!
route-map AS107-loadshare permit 10
 match ip as-path 10
 set local-preference 120
route-map AS107-loadshare permit 20
 set local-preference 80
!
```

Two Upstreams, One Local Peer – Full Routes

- Router D Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.5 remote-as 106
 neighbor 222.222.10.5 prefix-list rfc1918-deny in
 neighbor 222.222.10.5 prefix-list my-block out
!
ip prefix-list my-block permit 221.10.0.0/19
! See earlier in presentation for RFC1918 list
```

Two Upstreams, One Local Peer – Full Routes

- Router C configuration:
  - Accept full routes from AS107
  - Tag prefixes originated by AS107 and AS107's neighbouring ASes with local preference 120
    - Traffic to those ASes will go over AS107 link
  - Remaining prefixes tagged with local preference of 80
    - Traffic to other all other ASes will go over the link to AS106
- Router D configuration same as Router C without the route-map

Two Upstreams, One Local Peer – Full Routes

- Full routes from upstreams

  Expensive – needs 128Mbytes RAM today

  Need to play preference games

  Previous example is only an example – real life will need improved fine-tuning!

  Previous example doesn’t consider inbound traffic – see earlier presentation for examples

Two Upstreams, One Local Peer – Partial Routes

- Router C Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.1 remote-as 107
 neighbor 222.222.10.1 prefix-list rfc1918-nodef-deny in
 neighbor 222.222.10.1 prefix-list my-block out
 neighbor 222.222.10.1 filter-list 10 in
 neighbor 222.222.10.1 route-map tag-default-low in
!
ip prefix-list my-block permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
..next slide
```

Two Upstreams, One Local Peer – Partial Routes

```
! See earlier presentation for RFC1918 list
!
ip route 221.10.0.0 255.255.224.0 null0
!
ip as-path access-list 10 permit ^(107_)+$
ip as-path access-list 10 permit ^(107_)+_[0-9]+$
!
route-map tag-default-low permit 10
 match ip address prefix-list default
 set local-preference 80
route-map tag-default-low permit 20
!
```

Two Upstreams, One Local Peer – Partial Routes

- Router D Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.5 remote-as 106
 neighbor 222.222.10.5 prefix-list default in
 neighbor 222.222.10.5 prefix-list my-block out
!
ip prefix-list my-block permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 221.10.0.0 255.255.224.0 null0
```

Two Upstreams, One Local Peer – Partial Routes

- **Router C configuration:**

  Accept full routes from AS107

  (or get them to send less)

  Filter ASNs so only AS107 and AS107's neighbouring ASes are accepted

  Allow default, and set it to local preference 80

  Traffic to those ASes will go over AS107 link

  Traffic to other all other ASes will go over the link to AS106

  If AS106 link fails, backup via AS107 – and vice-versa

Two Upstreams, One Local Peer – Partial Routes

- Partial routes from upstreams

  Not expensive – only carry the routes necessary for loadsharing

  Need to filter on AS paths

  Previous example is only an example – real life will need improved fine-tuning!

  Previous example doesn't consider inbound traffic – see earlier presentation for examples

Two Upstreams, One Local Peer

- When upstreams cannot or will not announce default route
  - Because of operational policy against using “default-originate” on BGP peering
  - Solution is to use IGP to propagate default from the edge/peering routers

Two Upstreams, One Local Peer – Partial Routes

- **Router C Configuration**

```
router ospf 109
 default-information originate metric 30
 passive-interface Serial 0/0
!
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.1 remote-as 107
 neighbor 222.222.10.1 prefix-list rfc1918-deny in
 neighbor 222.222.10.1 prefix-list my-block out
 neighbor 222.222.10.1 filter-list 10 in
!
..next slide
```

Two Upstreams, One Local Peer – Partial Routes

```
ip prefix-list my-block permit 221.10.0.0/19
! See earlier presentation for RFC1918 list
!
ip route 221.10.0.0 255.255.224.0 null0
ip route 0.0.0.0 0.0.0.0 serial 0/0 254
!
ip as-path access-list 10 permit ^(107_)+$
ip as-path access-list 10 permit ^(107_)+_[0-9]+$
!
```

Two Upstreams, One Local Peer – Partial Routes

- **Router D Configuration**

```
router ospf 109
 default-information originate metric 10
 passive-interface Serial 0/0
!
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.5 remote-as 106
 neighbor 222.222.10.5 prefix-list deny-all in
 neighbor 222.222.10.5 prefix-list my-block out
!
..next slide
```

Two Upstreams, One Local Peer – Partial Routes

```
ip prefix-list deny-all deny 0.0.0.0/0 le 32
ip prefix-list my-block permit 221.10.0.0/19
! See earlier presentation for RFC1918 list
!
ip route 221.10.0.0 255.255.224.0 null0
ip route 0.0.0.0 0.0.0.0 serial 0/0 254
!
```

Two Upstreams, One Local Peer – Partial Routes

- Partial routes from upstreams

    Use OSPF to determine outbound path

    Router D default has metric 10 – primary outbound path

    Router C default has metric 30 – backup outbound path

    Serial interface goes down, static default is removed from routing table, OSPF default withdrawn

Service Provider Multihoming

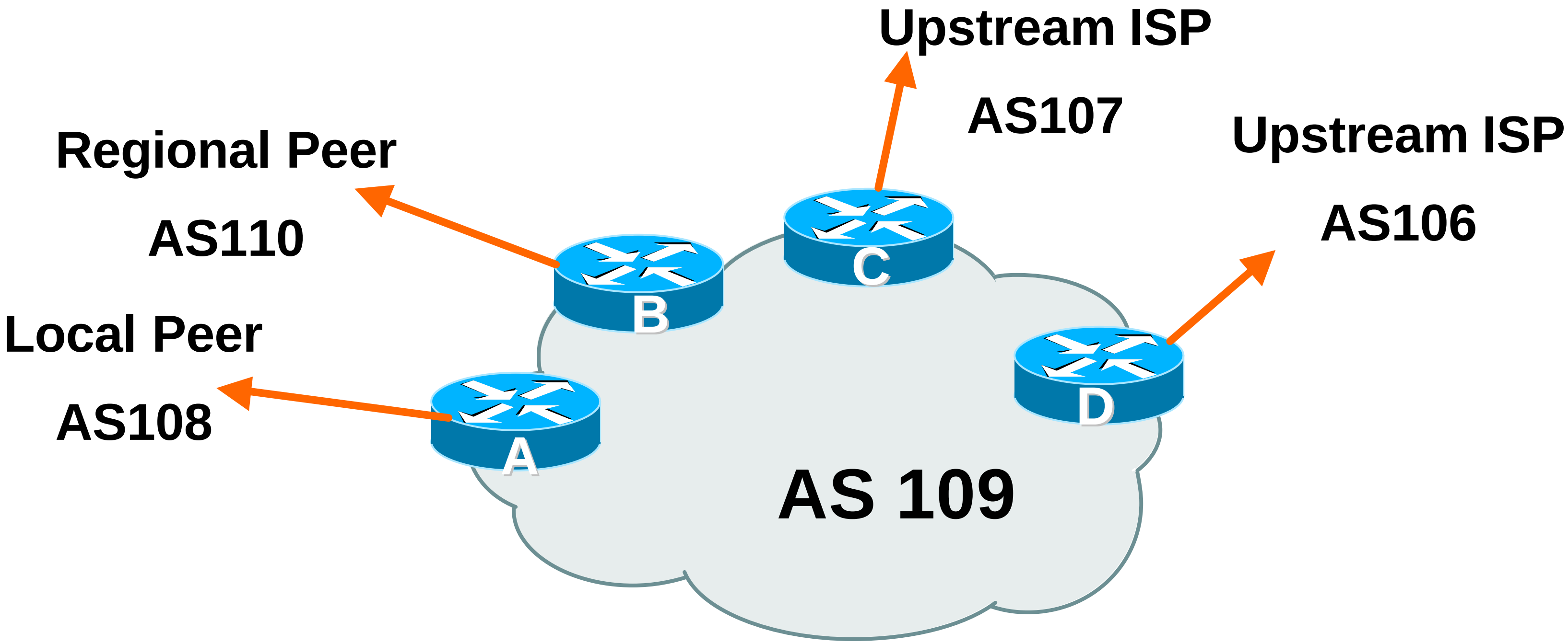
Two Upstreams, One regional peer, One local peer

Two Upstreams, One Regional and One Local Peer

- Announce /19 aggregate on each link
- Accept default route only from upstreams

  Either 0.0.0.0/0 or a network which can be used as default
- Accept all routes from local peer
- Accept all routes from regional peer

Two Upstreams, One Regional and One Local Peer



Two Upstreams, one Regional and One Local Peer

- Router A
  - Same routing configuration as in previous examples
  - Same hardware configuration

Two Upstreams, one Regional and One Local Peer

- Router B –Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.5 remote-as 110
 neighbor 222.222.10.5 prefix-list my-block out
 neighbor 222.222.10.5 filter-list 10 in
!
ip as-path access-list 10 permit ^(110_)+$
ip as-path access-list 10 permit ^(110_)+_[0-9]+$
!
ip prefix-list my-block permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.224.0 null0
```

Two Upstreams, one Regional and One Local Peer

- Configuration of Router B

  Take local AS from the regional peer

  Also take regional peer's customer and other ASes they give

  Local and regional traffic stays in the region

  The two upstreams use similar configuration to previously, loadsharing as required.

Service Provider Multihoming

Two US upstreams, two regional upstreams, and local peers

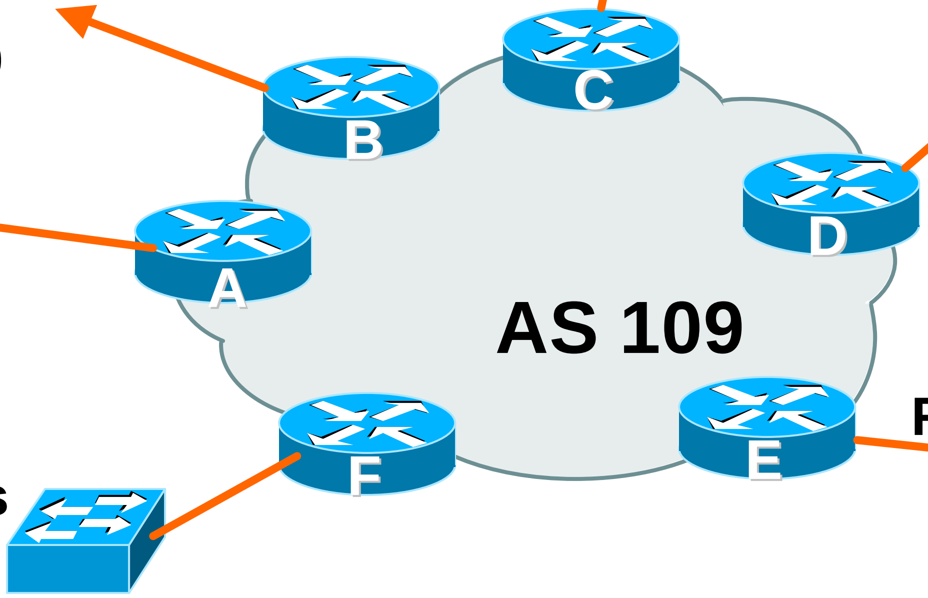
US and Regional Upstreams, Local Peers

- Announce /19 aggregate on each link
- Accept partial/default routes from upstreams

  For default, use 0.0.0.0/0 or a network which can be used as default

- Accept all routes from local peer
- Accept all partial routes from regional upstreams
- This is more complex, but a very typical scenario

US and Regional Upstreams, Local Peers



Upstream ISP

AS107

Regional Upstream

AS110

Upstream ISP

AS106

Local Peer

AS108

Regional Upstream

AS111

Local Peers

IXP

US and Regional Upstreams, Local Peers – Detail

- Router A – local private peer

  Accept all (local) routes

  Local traffic stays local

  Use prefix and/or AS-path filters

  Set >100 local preference on inbound announcements

US and Regional Upstreams, Local Peers – Detail

- Router F – local IXP peering

  Accept all (local) routes

  Local traffic stays local

  Use prefix and/or AS-path filters

  Set >100 local preference on inbound announcements

US and Regional Upstreams, Local Peers – Detail

- Router B – regional upstream

  They provide transit to Internet, but longer AS path than US Upstreams

  Accept all regional routes from them

    e.g. ^110_[0-9]+$

  Ask them to send default, or send a network you can use as default

    Set local pref on “default” to 60

  Will provide backup to Internet only when direct US links go down

US and Regional Upstreams, Local Peers – Detail

- Router E – regional upstream

  They provide transit to Internet, but longer AS path than US Upstreams

  Accept all regional routes from them

  e.g. ^111_[0-9]+$

  Ask them to send default, or send a network you can use as default

  Set local pref on "default" to 70

  Will provide backup to Internet only when direct US links go down

US and Regional Upstreams, Local Peers – Detail

- Router C – first US upstream

  Accept all their customer and AS neighbour routes from them

  e.g. ^107_[0-9]+$

  Ask them to send default, or send a network you can use as default

  Set local pref on "default" to 80

  Will provide backup to Internet only when link to second US upstream goes down

US and Regional Upstreams, Local Peers – Detail

- Router D – second US upstream

    Ask them to send default, or send a network you can use as default

        This has local preference 100 by default

    All traffic without any more specific path will go out this way

US and Regional Upstreams, Local Peers – Summary

- Local traffic goes to local peer and IXP
- Regional traffic goes to two regional upstreams
- Everything else is shared between the two US upstreams
- To modify loadsharing tweak what is heard from the two regionals and the first US upstream

  Best way is through modifying the AS-path filter

US and Regional Upstreams, Local Peers

- What about outbound announcement strategy?

  This is to determine incoming traffic flows

  /19 aggregate must be announced to everyone!

  /20 or /21 more specifics can be used to improve or modify loadsharing

  See earlier for hints and ideas

US and Regional Upstreams, Local Peers

- What about unequal circuit capacity?

  AS-path filters are very useful

- What if upstream will only give me full routing table or nothing

  AS-path and prefix filters are very useful

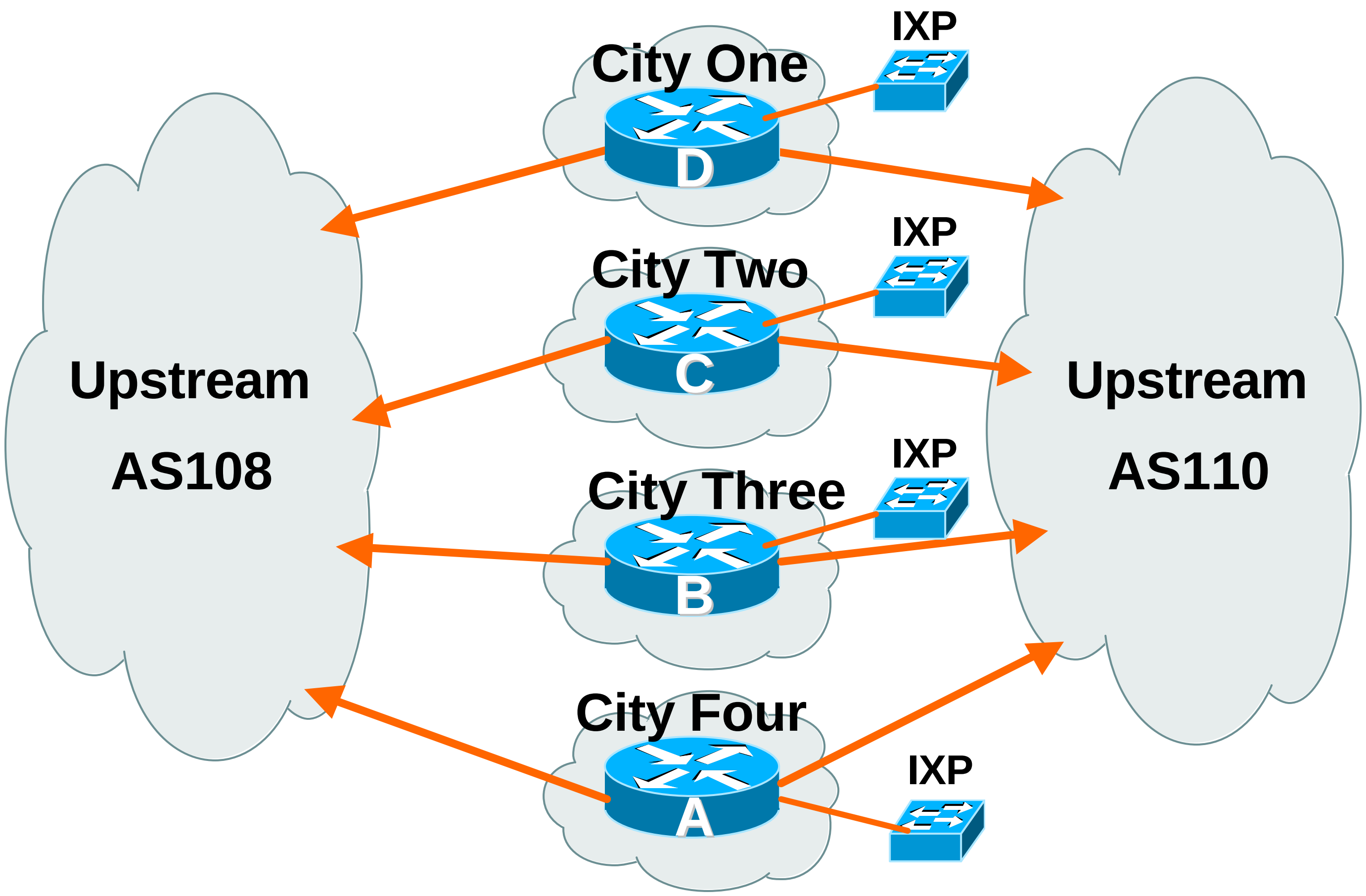
Service Provider Multihoming

Disconnected Backbone

Disconnected Backbone

- ISP runs large network
  - Network has no backbone, only large PoPs in each location
  - Each PoP multihomes to upstreams
  - Common in some countries where backbone circuits are hard to obtain

Disconnected Backbone



Disconnected Backbone

- Works with one AS number

  Not four – no BGP loop detection problem

- Each city operates as separate network

  Uses defaults and selected leaked prefixes for loadsharing

  Peers at local exchange point

Disconnected Backbone

- **Router A Configuration**

```
router bgp 109
 network 221.10.0.0 mask 255.255.248.0
 neighbor 222.200.0.1 remote-as 108
 neighbor 222.200.0.1 description AS108 – Serial 0/0
 neighbor 222.200.0.1 prefix-list default in
 neighbor 222.222.0.1 prefix-list my-block out
 neighbor 222.222.10.1 remote-as 110
 neighbor 222.222.10.1 description AS110 – Serial 1/0
 neighbor 222.222.10.1 prefix-list rfc1918-sua in
 neighbor 222.222.10.1 prefix-list my-block out
 neighbor 222.222.10.1 filter-list 10 in
!
```

…continued on next page…

Disconnected Backbone

```
ip prefix-list my-block permit 221.10.0.0/21
ip prefix-list default permit 0.0.0.0/0
!
ip as-path access-list 10 permit ^(110_)+$
ip as-path access-list 10 permit ^(110_)+_[0-9]+$
!…etc to achieve outbound loadsharing
!
ip route 0.0.0.0 0.0.0.0 Serial 1/0 250
ip route 221.10.0.0 255.255.248.0 null0
!
```

Disconnected Backbone

- Peer with AS108
  - Receive just default route
  - Announce /22 address
- Peer with AS110
  - Receive full routing table – filter with AS-path filter
  - Announce /22 address
  - Point backup static default – distance 252 – in case AS108 goes down

Disconnected Backbone

- Default ensures that disconnected parts of AS109 are reachable

  Static route backs up AS108 default

  No BGP loop detection – relying on default route

- Do not announce /19 aggregate

  No advantage in announcing /19 and could lead to problems

IDC Multihoming

IDC Multihoming

- IDCs typically are not registry members so don’t get their own address block

    Situation also true for small ISPs and “Enterprise Networks”

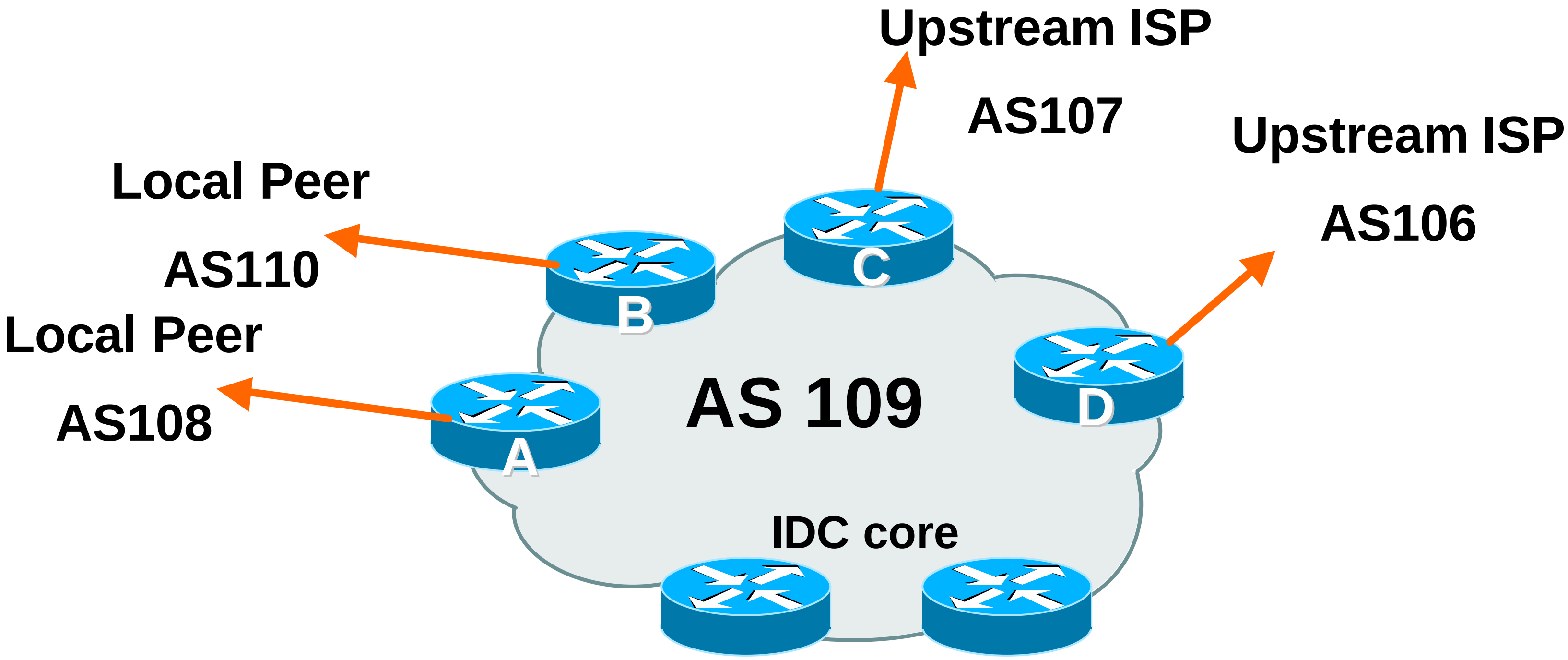
- Smaller address blocks being announced

    Address space comes from both upstreams

    Should be apportioned according to size of circuit to upstream

- Outbound traffic paths matter

Two Upstreams, Two Local Peers – IDC



Assigned /24 from AS107 and /23 from AS106.

Circuit to AS107 is 2Mbps, circuit to AS106 is 4Mbps

IDC Multihoming

- Router A and B configuration

  In: Should accept all routes from AS108 and AS110

  Out: Should announce all address space to AS108 and AS110

  Straightforward

IDC Multihoming

- Router C configuration

  In: Accept partial routes from AS107

  e.g. ^107_[0-9]+$

  In: Ask for a route to use as default

  set local preference on default to 80

  Out: Send /24, and send /23 with AS-PATH prepend of one AS

IDC Multihoming

- Router D configuration

  In: Ask for a route to use as default

  Leave local preference of default at 100

  Out: Send /23, and send /24 with AS-PATH prepend of one AS

IDC Multihoming Fine Tuning

- For local fine tuning, increase circuit capacity

  Local circuits usually are cheap

  Otherwise…

- For longer distance fine tuning

  In: Modify as-path filter on Router C

  Out: Modify as-path prepend on Routers C and D

  Outbound traffic flow is usual critical for an IDC so inbound policies need to be carefully thought out

IDC Multihoming Other Details

- Redundancy
  - Circuits are terminated on separate routers
- Apply thought to address space use
  - Request from both upstreams
  - Utilise address space evenly across IDC
    - Don’t start with /23 then move to /24 – use both blocks at the same time in the same proportion
    - Helps with loadsharing – yes, really!

IDC Multihoming Other Details

- What about failover?

  /24 and /23 from upstreams' blocks announced to the Internet routing table all the time

  No obvious alternative at the moment

  Conditional advertisement can help in steady state, but subprefixes still need to be announced in failover condition

Overseas Collocation

Why Overseas Collocation?

- Hard to re-terminate transoceanic circuit in case of “issues” with upstream ISP
- No Quality of Service
- No Control over infrastructure
- No Monitoring of link performance

Overseas Collocation

- Many ISPs collocate equipment in the US
  - install their own router(s) and other hardware (servers, caches,…)
  - establish peering relationships with US NSPs and domestic ISPs
  - enter transit agreements with several US NSPs
  - buy facilities management services
    - usually hardware maintenance, installation management

Overseas Collocation

- Many ISPs collocate equipment in the US

  US domestic circuits are “cheap”

  Easy to change your upstream

  Easy to have multiple upstreams

  Easy to implement QoS related features, service differentiation, etc...

Collocation

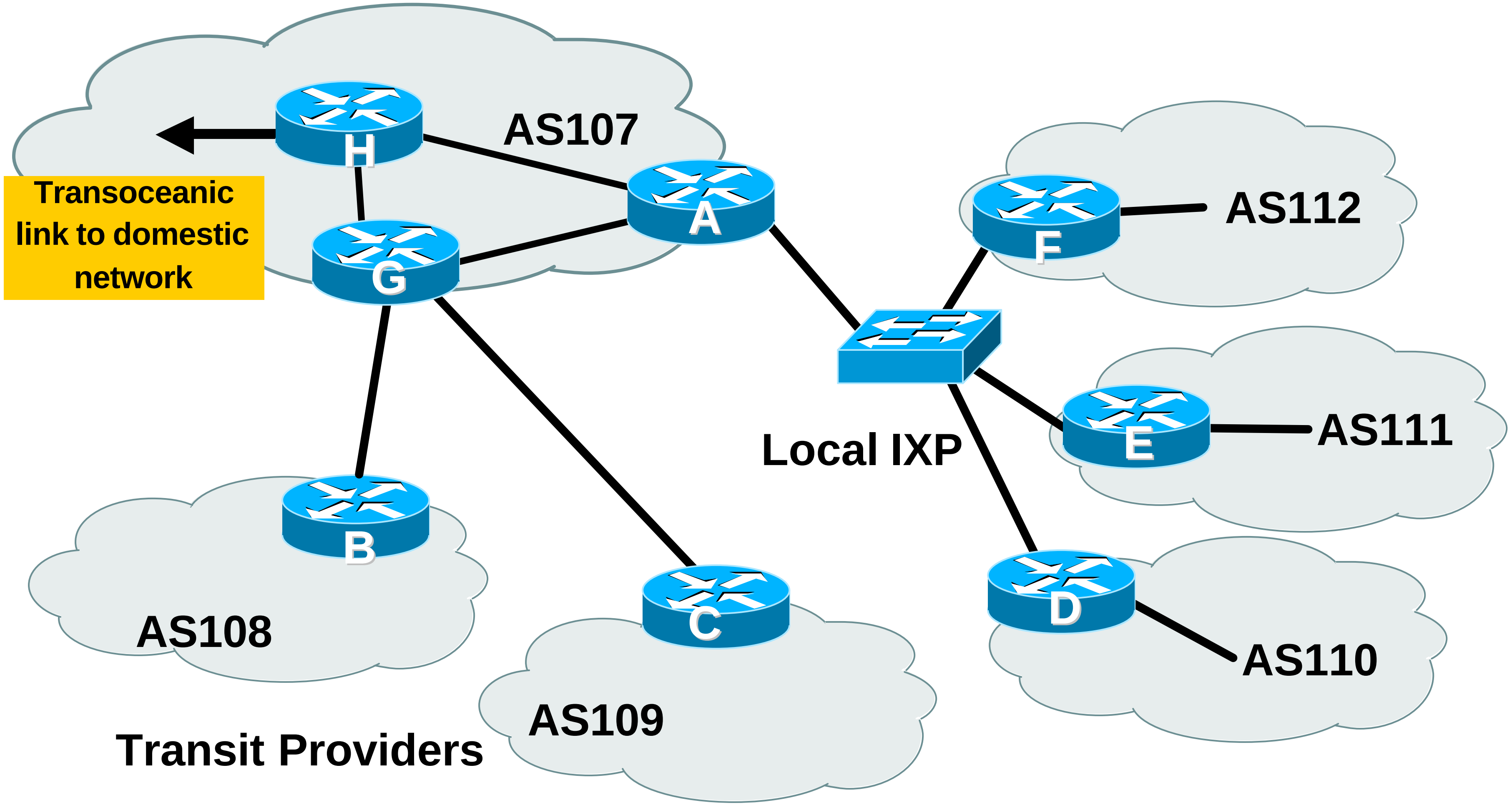
- **Common Scenario:**

  AS107 has collocate space in the US

  AS108 and AS109 are transit providers for AS107

  AS107 is also present at the local exchange point for regional peers

Collocation



Collocation

- **AS107**

  Router A is dedicated to peering at local IXP

  Router G is dedicated to links with the transit providers

  Router H is dedicated to the transoceanic link

Collocation Router A Configuration

```
interface loopback 0
 description Border Router Loopback
 ip address 221.0.0.1 255.255.255.255
!
interface fastethernet 0/0
 description Exchange Point LAN
 ip address 220.5.10.2 255.255.255.224
 ip verify unicast reverse-path
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
!
```

..next slide

Collocation
Router A Configuration

```
interface fastethernet 1/0
 description Direct 100Mbps Connection to Router G
 ip address 221.0.10.2 255.255.255.252
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
!
interface fastethernet 2/0
 description Direct 100Mbps Connection to Router H
 ip address 221.0.10.6 255.255.255.252
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
```

..next slide

Collocation
Router A Configuration

```
router bgp 107
 neighbor ibgp peer-group
 neighbor ibgp remote-as 107
 neighbor ibgp update-source loopback 0
 neighbor ixp-peers peer-group
 neighbor ixp-peers soft-reconfiguration in
 neighbor ixp-peers prefix-list myprefixes out
 neighbor 221.0.0.2 peer-group ibgp
 neighbor 221.0.0.2 description Router G - Upstream Peers
 neighbor 221.0.0.3 peer-group ibgp
 neighbor 221.0.0.3 description Router H - transpacific router
 neighbor 221.0.0.4 peer-group ibgp
 neighbor 221.0.0.4 description Router at HQ
..next slide
```

Collocation
Router A Configuration

```
 neighbor 220.5.10.4 remote-as 110
 neighbor 222.5.10.4 peer-group ixp-peers
 neighbor 222.5.10.4 prefix-list peer110 in
 neighbor 220.5.10.5 remote-as 111
 neighbor 222.5.10.5 peer-group ixp-peers
 neighbor 222.5.10.5 prefix-list peer111 in
 neighbor 220.5.10.6 remote-as 112
 neighbor 222.5.10.6 peer-group ixp-peers
 neighbor 222.5.10.6 prefix-list peer112 in
!
ip prefix-list myprefixes permit 221.10.0.0/19
ip prefix-list peer110 permit 222.12.0.0/19
ip prefix-list peer111 permit 222.18.128.0/19
ip prefix-list peer112 permit 222.1.32.0/19
```

Collocation
Router A Configuration

- Router A does NOT originate AS107's prefix block

  if router is disconnected from AS107 either locally or across the ocean, announcement could cause blackhole

- Prefix-list filtering is the minimum required

  usually include AS path filtering too

Collocation
Router G Configuration

```
interface loopback 0
 description Peering Router Loopback
 ip address 221.0.0.2 255.255.255.255
!
interface fastethernet 0/0
 description Direct 100Mbps Connection to Router A
 ip address 221.0.10.1 255.255.255.252
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
!
```

..next slide

Collocation
Router G Configuration

```
interface hssi 1/0
 description T3 link to BigISP
 ip address 222.0.0.2 255.255.255.252
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
!
interface hssi 2/0
 description T3 link to MegaISP
 ip address 218.6.0.2 255.255.255.252
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
```

..next slide

Collocation
Router G Configuration

```
router bgp 107
 neighbor ibgp peer-group
 neighbor ibgp remote-as 107
 neighbor ibgp update-source loopback 0
 neighbor 221.0.0.1 peer-group ibgp
 neighbor 221.0.0.1 description Router A - US Local IXP
 neighbor 221.0.0.1 prefix-list myprefixes out
 neighbor 221.0.0.3 peer-group ibgp
 neighbor 221.0.0.3 description Router H - transoceanic router
 neighbor 221.0.0.4 peer-group ibgp
 neighbor 221.0.0.4 description Router at HQ
```

..next slide

Collocation
Router G Configuration

```
 neighbor 222.0.0.1 remote-as 108
 neighbor 222.0.0.1 prefix-list myprefixes out
 neighbor 222.0.0.1 prefix-list rfc1918 in
 neighbor 218.6.0.1 remote-as 109
 neighbor 218.6.0.1 prefix-list myprefixes out
 neighbor 218.6.0.1 prefix-list rfc1918 in
!
ip prefix-list myprefixes permit 221.10.0.0/19
```

Collocation
Router G Configuration

- Router G accepts full BGP prefixes from both AS108 and AS109
- Router G announces AS107 prefix to upstreams
- Simple Example – policy may also be required for loadsharing etc

Collocation Router H Configuration

```
interface loopback 0
 description Peering Router Loopback
 ip address 221.0.0.3 255.255.255.255
!
interface fastethernet 0/0
 description Direct 100Mbps Connection to Router A
 ip address 221.0.10.5 255.255.255.252
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
!
```

...next slide

Collocation Router H Configuration

```
interface hssi 1/0
 description T3 link back to home
 ip address 221.1.0.1 255.255.255.252
 rate-limit output access-group 195 ..etc
 no ip directed-broadcast
 no ip proxy-arp
 no ip redirects
!
```

...next slide

Collocation Router H Configuration

```
router bgp 107
 neighbor ibgp peer-group
 neighbor ibgp remote-as 107
 neighbor ibgp update-source loopback 0
 neighbor 221.0.0.1 peer-group ibgp
 neighbor 221.0.0.1 description Router A - US Local IXP
 neighbor 221.0.0.2 peer-group ibgp
 neighbor 221.0.0.2 description Router G - peering router
 neighbor 221.0.0.4 peer-group ibgp
 neighbor 221.0.0.4 description Router at HQ
!
```

Collocation
Router H Configuration

- Router H is dedicated to transoceanic link

  part of ISP core iBGP mesh

- More complex configuration likely

  CAR, RED, etc

- More complex links likely

  e.g satellite uplink for low revenue latency insensitive traffic

Collocation

- Richer interconnectivity possible
- Better redundancy possible
- Overall advantage – control!

Service Provider Multihoming

Case Study

Case Study Requirements (1)

- ISP needs to multihome:

  To AS5400 in Europe

  To AS2516 in Japan

  /19 allocated by APNIC

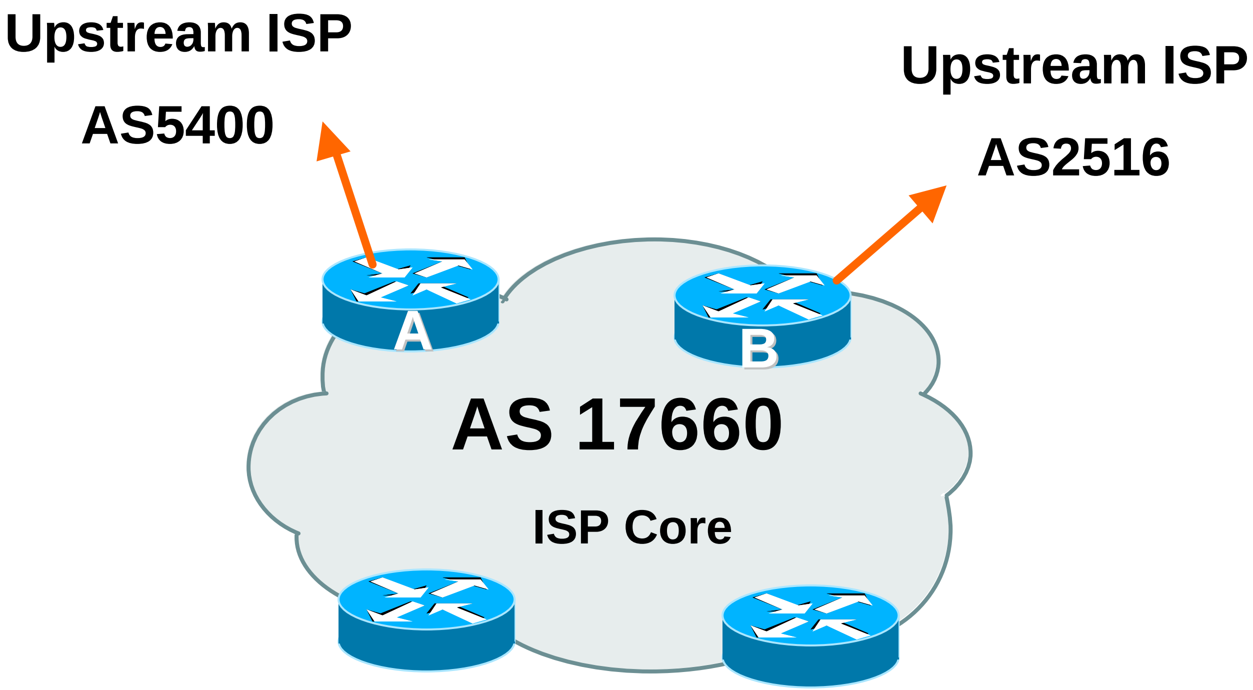
  AS 17660 assigned by APNIC

  1Mbps circuits to both upstreams

Case Study Requirements (2)

- ISP wants:
  - Symmetric routing and equal link utilisation in and out (as close as possible)
    - international circuits are expensive
  - Has two 2600 border routers with 64Mbytes memory
    - Cannot afford to upgrade memory or hardware on border routers or internal routers
- “Philip, make it work, please”

Case Study



Allocated /19 from APNIC

Circuit to AS5400 is 1Mbps, circuit to AS2516 is 1Mbps

Case Study

- Both providers stated that routers with 128Mbytes memory required for AS17660 to multihome

  Wrong!

  Full routing table is rarely required or desired

- Solution:

  Accept default from one upstream

  Accept partial prefixes from the other

Case Study
Inbound Loadsharing

- **First cut: Went to a few US Looking Glasses**

  Checked the AS path to AS5400

  Checked the AS path to AS2516

  AS2516 was one hop “closer”

  Sent AS-PATH prepend of one AS on AS2516 peering

Case Study
Inbound Loadsharing

- Refinement

  Did not need any

  First cut worked, seeing on average 600kbps inbound on each circuit

  Does vary according to time of day, but this is as balanced as it can get, given customer profile

  ☺

Case Study
Outbound Loadsharing

- **First cut:**
  - **Requested default from AS2516**
  - **Requested full routes from AS5400**
- **Then looked at my Routing Report**
  - **Picked the top 5 ASNs and created a filter-list**
    - **If 701, 1, 7018, 1239 or 7046 are in AS-PATH, prefixes are discarded**
    - **Allowed prefixes originated by AS5400 and up to two AS hops away**
  - **Resulted in 32000 prefixes being accepted in AS17660**

Case Study
Outbound Loadsharing

- Refinement
  - 32000 prefixes quite a lot, seeing more outbound traffic on the AS5400 path
  - Traffic was very asymmetric
    - out through AS5400, in through AS2516
  - Added the next 3 ASNs from the Top 20 list
    - 209, 2914 and 3549
  - Now seeing 14000 prefixes
  - Traffic is now evenly loadshared outbound
    - Around 200kbps on average
    - Mostly symmetric

Case Study
Configuration Router A

```
router ospf 100
 log-adjacency-changes
 passive-interface default
 no passive-interface Ethernet0/0
 default-information originate metric 20
!
router bgp 17660
 no synchronization
 no bgp fast-external-fallover
 bgp log-neighbor-changes
 bgp deterministic-med
...next slide
```

Case Study Configuration Router A

```
neighbor 166.49.165.13 remote-as 5400
neighbor 166.49.165.13 description eBGP multihop to AS5400
neighbor 166.49.165.13 ebgp-multihop 5
neighbor 166.49.165.13 update-source Loopback0
neighbor 166.49.165.13 prefix-list in-filter in
neighbor 166.49.165.13 prefix-list out-filter out
neighbor 166.49.165.13 filter-list 1 in
neighbor 166.49.165.13 filter-list 3 out
!
prefix-list in-filter  deny rfc1918etc in
prefix-list out-filter permit 202.144.128.0/19
!
ip route 0.0.0.0 0.0.0.0 serial 0/0 254
```

...next slide

Case Study
Configuration Router A

```
ip as-path access-list 1 deny _701_
ip as-path access-list 1 deny _1_
ip as-path access-list 1 deny _7018_
ip as-path access-list 1 deny _1239_
ip as-path access-list 1 deny _7046_
ip as-path access-list 1 deny _209_
ip as-path access-list 1 deny _2914_
ip as-path access-list 1 deny _3549_
ip as-path access-list 1 permit _5400$
ip as-path access-list 1 permit _5400_[0-9]+$
ip as-path access-list 1 permit _5400_[0-9]+_[0-9]+$
ip as-path access-list 1 deny .*
ip as-path access-list 3 permit ^$
!
```

Case Study
Configuration Router B

```
router ospf 100
 log-adjacency-changes
 passive-interface default
 no passive-interface Ethernet0/0
 default-information originate
!
router bgp 17660
 no synchronization
 no auto-summary
 no bgp fast-external-fallover
...next slide
```

Case Study
Configuration Router B

```
 bgp log-neighbor-changes
 bgp deterministic-med
 neighbor 210.132.92.165 remote-as 2516
 neighbor 210.132.92.165 description eBGP peering
 neighbor 210.132.92.165 soft-reconfiguration inbound
 neighbor 210.132.92.165 prefix-list default-route in
 neighbor 210.132.92.165 prefix-list out-filter out
 neighbor 210.132.92.165 route-map as2516-out out
 neighbor 210.132.92.165 maximum-prefix 100
 neighbor 210.132.92.165 filter-list 2 in
 neighbor 210.132.92.165 filter-list 3 out
!
```

...next slide

Case Study
Configuration Router B

```
!
prefix-list default-route permit 0.0.0.0/0
prefix-list out-filter permit 202.144.128.0/19
!
ip as-path access-list 2 permit _2516$
ip as-path access-list 2 deny .*
ip as-path access-list 3 permit ^$
!
route-map as2516-out permit 10
 set as-path prepend 17660
!
```

Configuration Summary

- Router A

  Hears full routing table – throws away most of it

  AS5400 BGP options are all or nothing

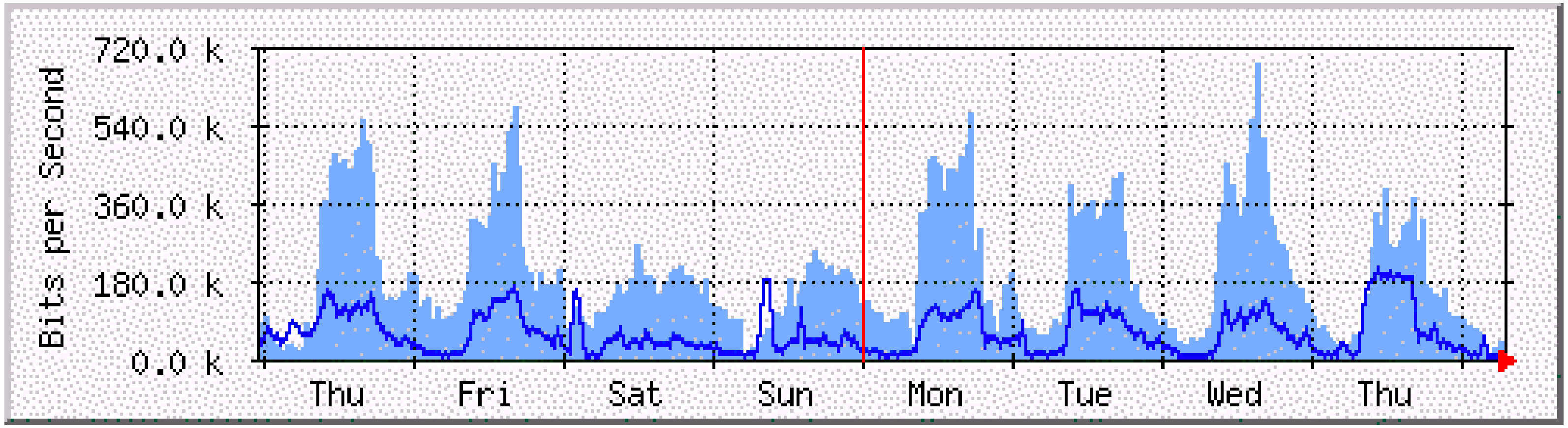
  Static default pointing to serial interface – if link goes down, OSPF default removed

- Router B

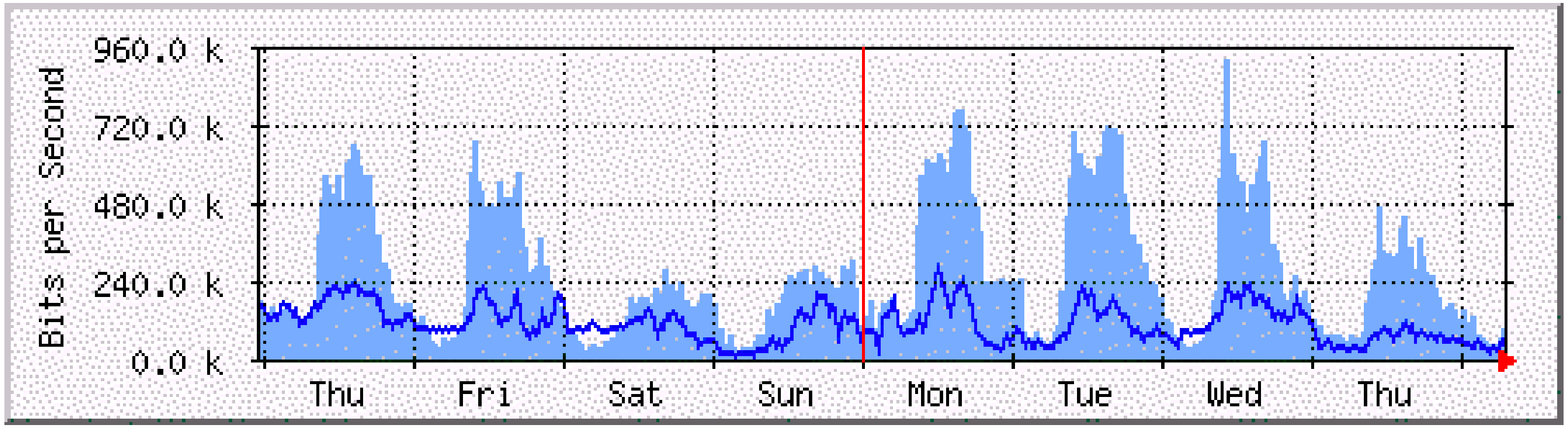
  Hears default from AS2516

  If default disappears (BGP goes down or link goes down), OSPF default is removed

Case Study
MRTG Graphs



Router A to AS5400



Router B to AS2516

Case Study Summary

- **Multihoming is not hard, really!**

  Needs a bit of thought, a bit of planning

  Use this case study as an example strategy

  Does not require sophisticated equipment, big memory, fast CPUs…

BGP for Internet Service Providers

- BGP Basics (quick recap)
- Scaling BGP
- Deploying BGP in an ISP network
- Trouble & Troubleshooting
- Multihoming Examples
- Using Communities

Communities

Community usage

- RFC1998
- Examples of SP applications

RFC1998

- Informational RFC
- Describes how to implement loadsharing and backup on multiple inter-AS links

  BGP communities used to determine local preference in upstream’s network
- Gives control to the customer
- Simplifies upstream’s configuration

  simplifies network operation!

RFC1998

- **Community values defined to have particular meanings:**

ASx:100	set local pref 100	preferred route
ASx:90	set local pref 90	backup route if dualhomed on ASx
ASx:80	set local pref 80	main link is to another ISP with same AS path length
ASx:70	set local pref 70	main link is to another ISP

RFC1998

- Sample Customer Router Configuration

```
router bgp 107
 neighbor x.x.x.x remote-as 109
 neighbor x.x.x.x description Backup ISP
 neighbor x.x.x.x route-map config-community out
 neighbor x.x.x.x send-community
!
ip as-path access-list 20 permit ^$
ip as-path access-list 20 deny .*
!
route-map config-community permit 10
 match as-path 20
 set community 109:90
```

RFC1998

- **Sample ISP Router Configuration**

```
! Homed to another ISP
ip community-list 70 permit 109:70
! Homed to another ISP with equal ASPATH length
ip community-list 80 permit 109:80
! Customer backup routes
ip community-list 90 permit 109:90
!
route-map set-customer-local-pref permit 10
 match community 70
 set local-preference 70
```

RFC1998

- Sample ISP Router Configuration

```
route-map set-customer-local-pref permit 20
 match community 80
 set local-preference 80
!
route-map set-customer-local-pref permit 30
 match community 90
 set local-preference 90
!
route-map set-customer-local-pref permit 40
 set local-preference 100
```

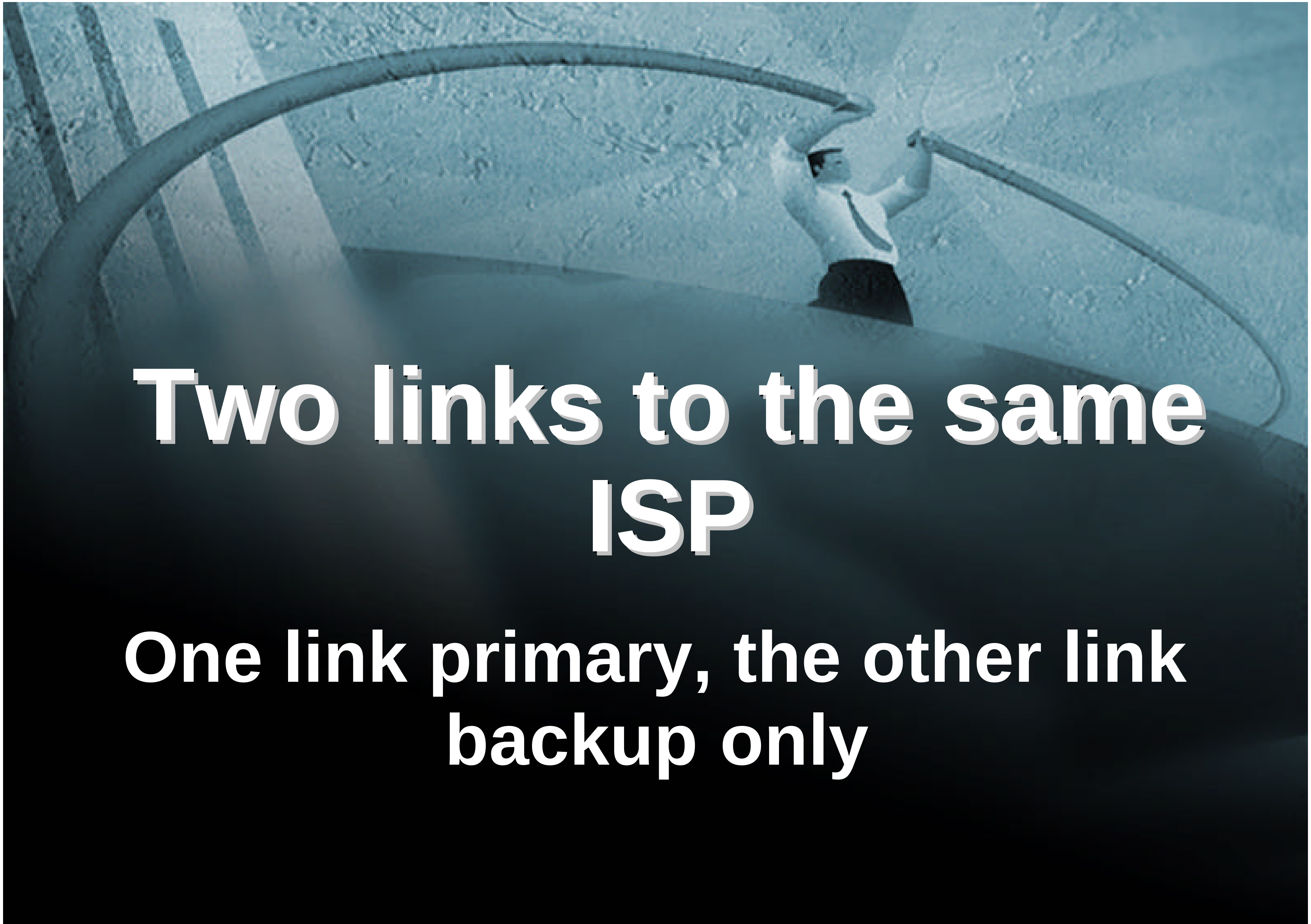
RFC1998

- Supporting RFC1998

  many ISPs do, more should

  check AS object in the Internet Routing Registry

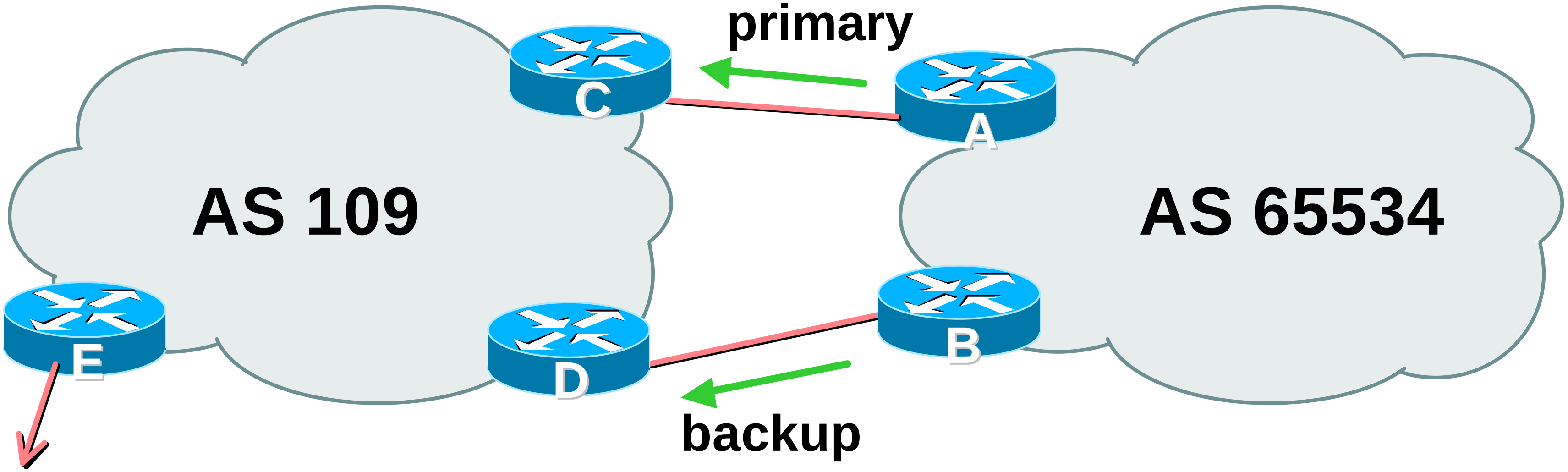
  if you do, insert comment in AS object in the IRR



Two links to the same ISP

One link primary, the other link backup only

Two links to the same ISP



- AS109 proxy aggregates for AS 65534

Two links to the same ISP (one as backup only)

- Announce /19 aggregate on each link

  primary link makes standard announcement

  backup link sends community

- When one link fails, the announcement of the /19 aggregate via the other link ensures continued connectivity

Two links to the same ISP (one as backup only)

- Router A Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 description RouterC
 neighbor 222.222.10.2 prefix-list aggregate out
 neighbor 222.222.10.2 prefix-list default in
!
ip prefix-list aggregate permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
```

Two links to the same ISP (one as backup only)

- **Router B Configuration**

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.6 remote-as 109
 neighbor 222.222.10.6 description RouterD
 neighbor 222.222.10.6 send-community
 neighbor 222.222.10.6 prefix-list aggregate out
 neighbor 222.222.10.6 route-map routerD-out out
 neighbor 222.222.10.6 prefix-list default in
 neighbor 222.222.10.6 route-map routerD-in in
!
..next slide
```

Two links to the same ISP (one as backup only)

```
ip prefix-list aggregate permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
route-map routerD-out permit 10
 match ip address prefix-list aggregate
 set community 109:90
route-map routerD-out permit 20
!
route-map routerD-in permit 10
 set local-preference 90
!
```

Two links to the same ISP (one as backup only)

- Router C Configuration (main link)

```
router bgp 109
 neighbor 222.222.10.1 remote-as 65534
 neighbor 222.222.10.1 default-originate
 neighbor 222.222.10.1 prefix-list Customer in
 neighbor 222.222.10.1 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
```

Two links to the same ISP (one as backup only)

- Router D Configuration (backup link)

```
router bgp 109
 neighbor 222.222.10.5 remote-as 65534
 neighbor 222.222.10.5 default-originate
 neighbor 222.222.10.5 prefix-list Customer in
 neighbor 222.222.10.5 route-map bgp-cust-in in
 neighbor 222.222.10.5 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
..next slide
```

Two links to the same ISP (one as backup only)

```
  ip prefix-list Customer permit 221.10.0.0/19
  ip prefix-list default permit 0.0.0.0/0
  !
  ip community-list 90 permit 109:90
  !
<snip>
  route-map bgp-cust-in permit 30
   match community 90
   set local-preference 90
  route-map bgp-cust-in permit 40
   set local-preference 100
```

More community definitions

Some working examples

Background

- RFC1998 is okay for “simple” multihomed customers

  assumes that upstreams are interconnected

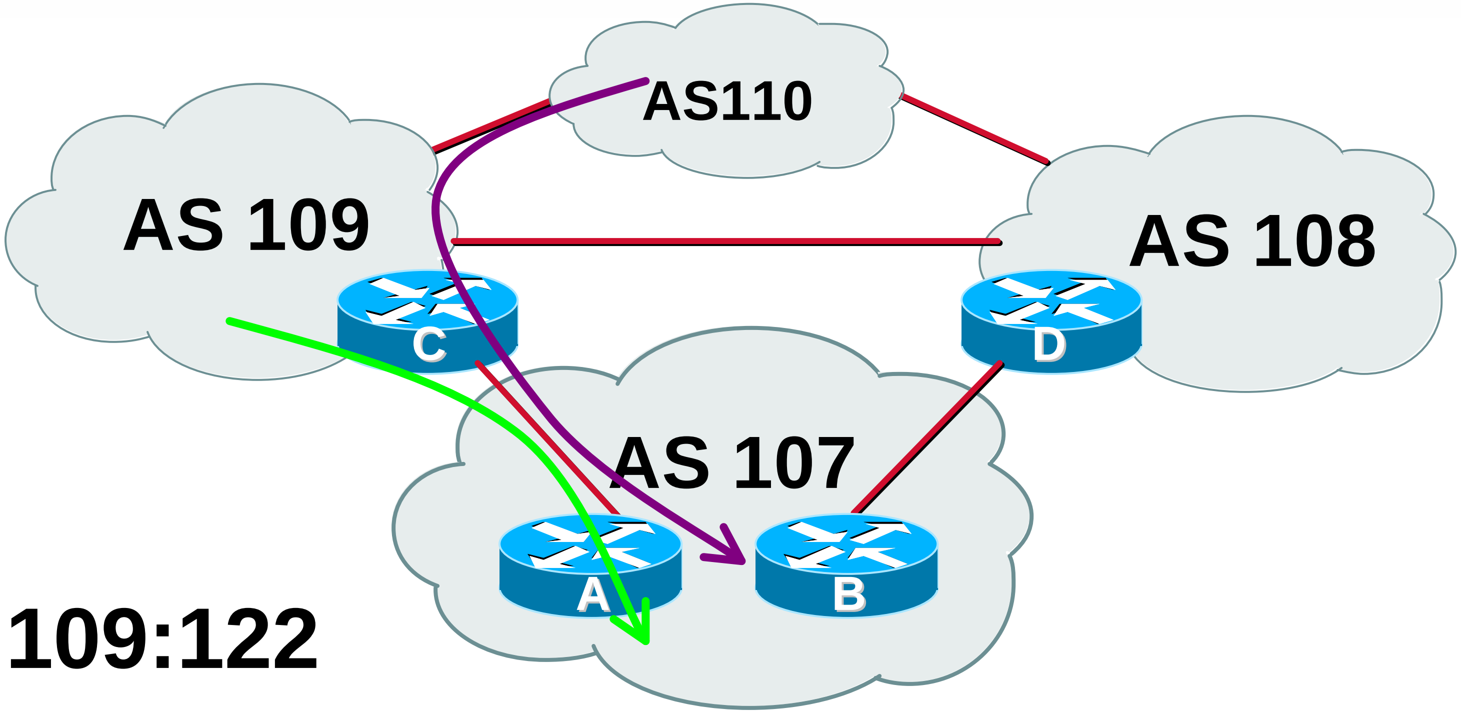
- ISPs create many other communities to handle more complex situations

More community definitions

ASx:122	set local pref 120 and set local pref high on upstreams
ASx:121	set local pref 120 and set local pref low on upstreams
ASx:120	set local pref 120 (opposite to ASx:80)
ASx:82	set local pref 80 and set local pref high on upstreams
ASx:81	set local pref 80 and set local pref low on upstreams
ASx:21	announce to customers with no-export
ASx:20	announce only to backbone and customers
ASx:3	set 3x as-path prepend on peer announcement
ASx:2	set 2x as-path prepend on peer announcement
ASx:1	set 1x as-path prepend on peer announcement

(and variations on this theme depending on local conditions, e.g. IXPs, domestic vs. international transit, etc.)

Examples

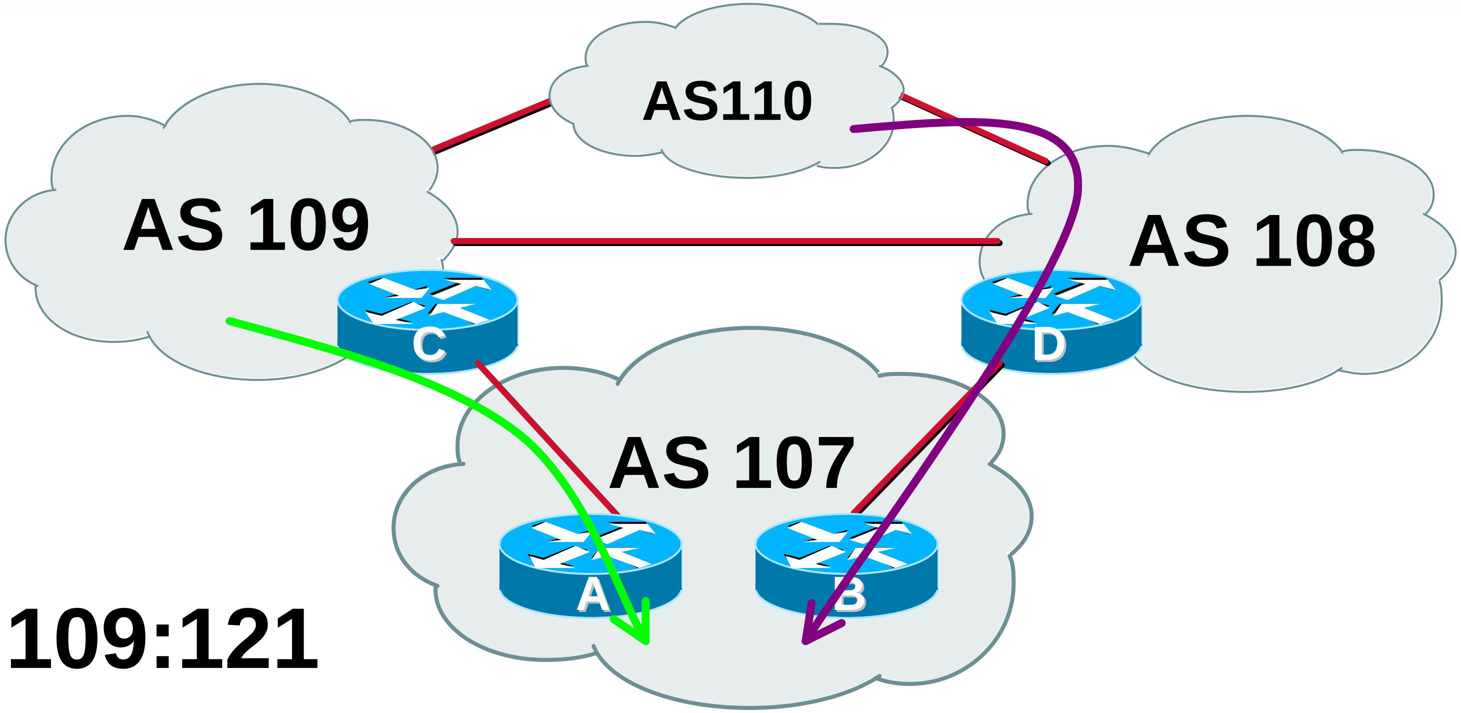


- **109:122**

  traffic in AS109 comes directly to you

  traffic in AS110 sent to AS109 rather than best path

Examples



- **109:121**

  traffic in AS109 comes directly to you

  traffic in AS110 sent to AS108 rather than best path

Examples

- 109:3

  prepend any announcements to peers of AS109 with 109_109_109

  "AS109 is my backup transit AS"

- 109:20

  Don't announce outside upstream's customer base

  "AS109 provides local connections only"

  109:21 is very similar

Service Providers use of Communities

Some working examples

Some ISP Examples

- ISPs create communities to give customers bigger routing policy control
- Public policy is usually listed in the IRR

  Following examples are all in the IRR
- Consider creating communities to give policy control to customers

  Reduces technical support burden

  Reduces the amount of router reconfiguration, and the chance of mistakes

Some ISP Examples
Connect.com.au

```
aut-num:       AS2764
as-name:       ASN-CONNECT-NET
descr:         connect.com.au pty ltd
admin-c:       CC89
tech-c:        MP151
remarks:       Community  Definition
remarks:       ------------------------------------------------
remarks:       2764:1 Announce to "domestic" rate ASes only
remarks:       2764:2 Don't announce outside local POP
remarks:       2764:3 Lower local preference by 25
remarks:       2764:4 Lower local preference by 15
remarks:       2764:5 Lower local preference by 5
remarks:       2764:6 Announce to non customers with "no-export"
remarks:       2764:7 Only announce route to customers
remarks:       2764:8 Announce route over satellite link
notify:        routing@connect.com.au
mnt-by:        CONNECT-AU
changed:       mrp@connect.com.au 19990506
source:        CCAIR
```

Some ISP Examples UUNET Europe

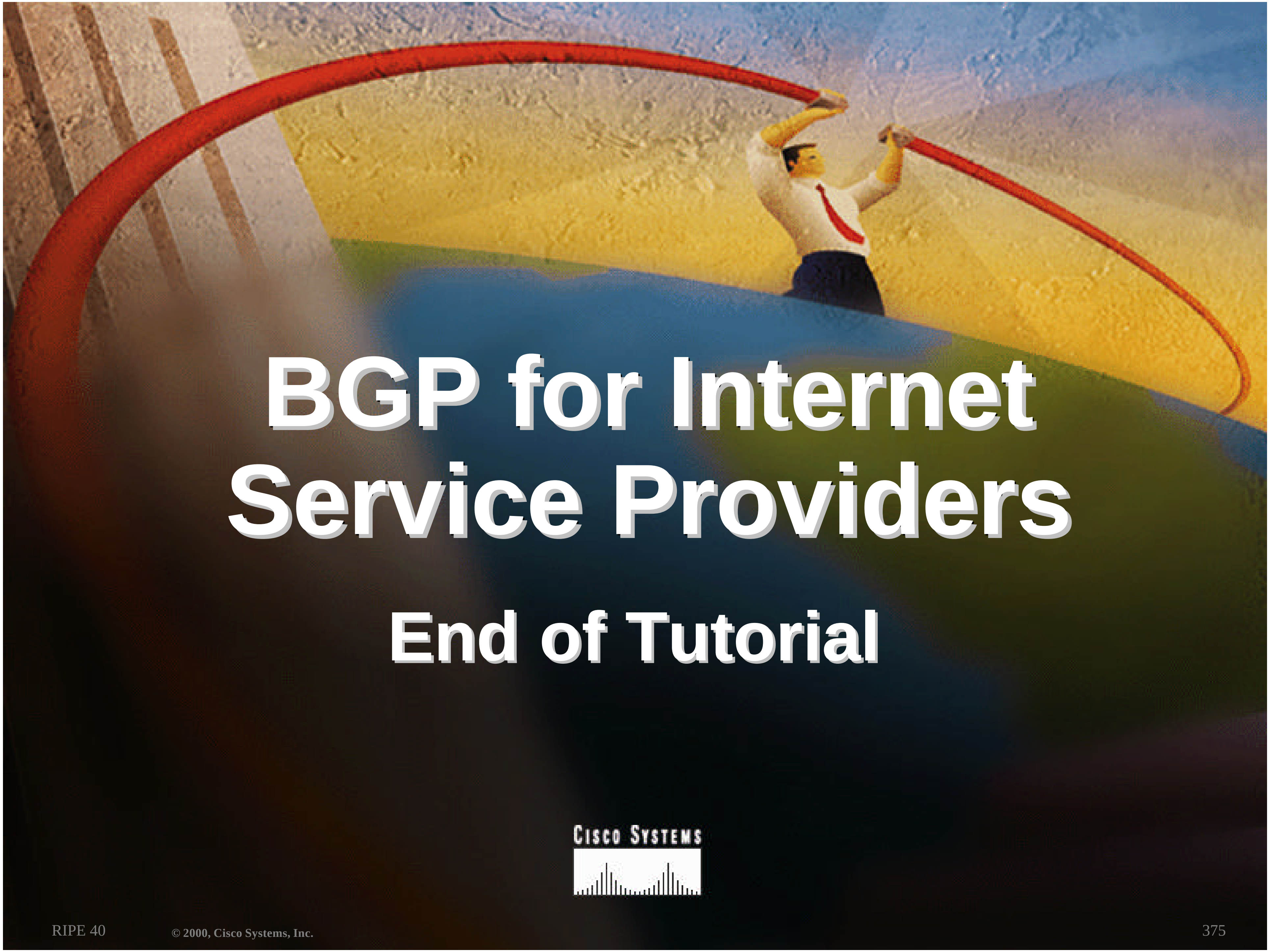
```
aut-num: AS702
as-name: AS702
descr:   UUNET - Commercial IP service provider in Europe
remarks: -------------------------------------------------------------
remarks: UUNET uses the following communities with its customers:
remarks: 702:80  Set Local Pref 80 within AS702
remarks: 702:120 Set Local Pref 120 within AS702
remarks: 702:20  Announce only to UUNET AS'es and UUNET customers
remarks: 702:30  Keep within Europe, don't announce to other UUNET AS's
remarks: 702:1   Prepend AS702 once at edges of UUNET to Peers
remarks: 702:2   Prepend AS702 twice at edges of UUNET to Peers
remarks: 702:3   Prepend AS702 thrice at edges of UUNET to Peers
remarks: Details of UUNET's peering policy and how to get in touch with
remarks: UUNET regarding peering policy matters can be found at:
remarks: http://www.uu.net/peering/
remarks: --------------------------------------------------------------
mnt-by:  UUNET-MNT
changed: eric-apps@eu.uu.net 20010928
source:  RIPE
```

Some ISP Examples Concert Europe

```
aut-num:      AS5400
as-name:      CIPCORE
descr:        Concert European Core Network
remarks:      Communities scheme:
remarks:      The following BGP communities can be set by Concert BGP
remarks:      customers to affect announcements to major peerings.
remarks:
remarks:      Community to                           Community to
remarks:      Not announce      To peer:             AS prepend 5400
remarks:
remarks:      5400:1000         European peers       5400:2000
remarks:      5400:1001         Ebone (AS1755)       5400:2001
remarks:      5400:1002         Eunet (AS286)        5400:2002
remarks:      5400:1003         Unisource (AS3300)   5400:2003
<snip>
remarks:      5400:1100         US peers             5400:2100
notify:       peertech@concert.net
mnt-by:       CIP-MNT
source:       RIPE
```

BGP for Internet Service Providers

- BGP Basics (quick recap)
- Scaling BGP
- Deploying BGP in an ISP network
- Trouble & Troubleshooting
- Multihoming Examples
- Using Communities



BGP for Internet Service Providers

End of Tutorial

Cisco Systems